Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHZ Band	ET Docket No. 13-49

COMMENTS OF THE NATIONAL CABLE & TELECOMMUNICATIONS ASSOCIATION ON THE REQUEST TO UPDATE THE U-NII-4 BAND RECORD

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I. INTRODUCTION AND SUMMARY.

The Commission began this proceeding with the recognition that demand for wireless broadband services has experienced staggering growth, and that additional unlicensed spectrum in the 5 GHz U-NII bands is important to meet that demand. If Wi-Fi's remarkable trajectory and the economic benefits it brings are to continue, the Commission must act quickly to designate new unlicensed spectrum. Because the 5 GHz U-NII-4 band presents the best—and only near-term—opportunity to do so, the National Cable & Telecommunications Association (NCTA) strongly supports the Commission's efforts to update and refresh the U-NII-4 record.[1]

As it considers how to best promote sharing between unlicensed broadband and dedicated short range communications (DSRC) in U-NII-4, the Commission should account for how each technology has developed. When the Commission adopted the existing 75 megahertz allocation, both DSRC and 5 GHz Wi-Fi technologies were nascent. Circumstances have changed over the past 17 years. Despite having every opportunity to use the 5.9 GHz band, DSRC proponents still have not made meaningful use of the band, allowing 75 megahertz to lay fallow for more than a decade. By comparison, Wi-Fi in the 5 GHz band has delivered broadband access to hundreds of millions of consumers every day. Sharing in the 5.9 GHz band should reflect this fact.

To be clear, NCTA supports efforts to use wireless technology to make Americans safer on the road. But, for the reasons explained below, the Commission need not sacrifice broadband connectivity, economic opportunity, and other benefits that faster and more ubiquitous Wi-Fi will generate in order to achieve that goal.

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1 *The Commission Seeks to Update and Refresh the Record in the "Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band" Proceeding*, ET Docket No. 13-49, Public Notice, FCC 16-68 (rel. June 1, 2016) (*Public Notice*).

First, although DSRC proponents' advocacy in this proceeding has focused on crash avoidance and related safety functions, these applications require only a small portion of the 75 megahertz of spectrum claimed by DSRC interests. Many other uses DSRC interests have planned for the U-NII-4 band—but have not highlighted in this proceeding—are commercial applications that are not safety services. Furthermore, many of these same services are already offered using non-DSRC spectrum today in more efficient ways that do not preclude other spectrum uses.

The Commission should not grant non-crash avoidance DSRC operations the extraordinary special status of a free nationwide exclusive license. And the Commission should not privilege these applications over other operations simply because they use the DSRC protocol. In setting aside spectrum for the exclusive use of DSRC—without auction or other competitive bidding process—Congress and the Commission emphasized safety-of-life applications. *Only* those applications justify departing from Commission and Administration directives to share spectrum and the policy of regulatory parity. If automotive companies defend their need for the band for safety reasons, the Commission should limit their special rights to safety applications.

Second, the Commission can best facilitate sharing between DSRC and unlicensed uses in the 5.9 GHz band by adopting an approach that contemplates the use of crash-avoidance and related DSRC technologies only in the portion of the U-NII-4 band needed for these activities, and then designate these frequencies for their exclusive use. The U-NII-4 band represents the best opportunity for the Commission to provide access to additional unlicensed broadband technologies, including gigabit Wi-Fi. Rechannelization achieves that goal by fully protecting safety functions and, at the same time, enabling meaningful sharing in the rest of the band—all in a manner consistent with the emerging international consensus regarding use of the 5 GHz band.

Finally, as the Commission gathers information to inform its decisions on U-NII-4 rules, the Commission should carefully design its test plan to ensure that it produces meaningful data about the impact of Wi-Fi sharing proposals on DSRC performance. Specifically, the Commission's testing strategy should: (1) focus on the provision of basic safety messages, which are the core DSRC function; (2) investigate multiple sharing approaches; (3) investigate the impact to DSRC of the existing co-primary system; and (4) measure real-world performance and efficacy of DSRC safety applications. The Commission also should not impose specific form factor or other requirements on test devices.

By taking these steps, the Commission can enable the continued success of Wi-Fi and other unlicensed broadband uses while facilitating the ongoing development of crash-avoidance and related technologies. Thoughtful implementation of a DSRC rechannelization approach ensures that the Commission need not choose between these important priorities.

II. CRASH AVOIDANCE AND RELATED DSRC FUNCTIONS REQUIRE ONLY A PORTION OF THE U-NII-4 BAND.

In the *Public Notice* the Commission seeks comment on the projected spectrum needs for DSRC operations, including anticipated "safety" and "non-safety" applications.[2] Notwithstanding the fact that the Commission initially allocated 75 megahertz for DSRC applications, DSRC operations require far less spectrum for crash-avoidance functions and "safety-adjacent" services. If DSRC proponents also wish to deploy non-safety services, they can do so using the remaining spectrum in the 5.9 GHz. But the Commission should not

[2] *Id.* at 8.

subsidize these non-safety services with the extraordinary provision of exclusive licenses without an auction.

A. 30 Megahertz of Spectrum is More Than Sufficient for Crash Avoidance and "Safety-Adjacent" DSRC Applications.

Both the existing DSRC band plan and the rechannelization sharing proposal contemplate the use of up to 30 megahertz for safety-related communications.[3] This amount of spectrum is more than sufficient to accommodate the vehicle-to-vehicle safety warning (V2VSW) systems that have been the primary focus of the National Highway Traffic Safety Administration (NHTSA) and the Department of Transportation's (DoT) 5.9 GHz DSRC research, and are the only services that NHTSA is considering mandating in its pending rulemaking. This 30 megahertz is also fully sufficient for any "safety-adjacent" vehicle-to-infrastructure (V2I) communications that DSRC proponents seek to deploy.

As set forth in the attached Technical Appendix, based on the publicly available information about V2VSWs, DSRC operations require no more than 10 megahertz of spectrum for the exchange of basic safety messages (BSMs).[4] DSRC proponents have also argued that DSRC systems can utilize safety-adjacent applications using V2I communications in addition to the exchange of BSMs, and in some cases, these V2I communications may be time-sensitive.[5] As the Technical Appendix explains, however, most of the safety-adjacent V2I services

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[3] *See* 47 C.F.R. § 95.1511(a) (designating two 10 megahertz service channels for safety of life, along with a 10 megahertz control channel); *Public Notice* at 7 (describing the band plan for the rechannelization sharing proposal).

[4] *See* Rob Alderfer, et al., *Optimizing DSRC Safety Efficacy and Spectrum Utility in the 5.9 GHz Band* at 8, 13-14 (Oct. 2014) (attached to these comments) (Technical Appendix); *see also supra* Section IV. C (describing European conclusion that safety-related functions can limited to 30 megahertz of spectrum).

[5] *See id.* at 13-14.

envisioned for the DSRC band—stop signal warnings, reduced speed warnings, railroad crossing warnings, weather warnings, and the like—likely will not require the low latency that BSMs rely upon.[6] Furthermore, there is no reliable record evidence that these applications have the same spectral needs or have the same interference sensitivities as BSM signals.

Nevertheless, the Commission could designate a third safety channel for V2I communications, control channel switching functions, or possibly security-related communications adjacent to the provision of V2VSWs.[7] Indeed, the rechannelization plan described in the *Public Notice* contemplates exactly this approach.[8] But even with this addition, as the attached Technical Appendix makes clear, allocating 30 megahertz for the exclusive use of time-sensitive V2VSW and safety-adjacent V2I applications would be more than adequate to accommodate all current and planned safety-related applications.[9]

B. Many of the Services DSRC Interests Plan for the 5850-5925 MHz Band Have Nothing to Do with Safety.

DSRC advocates have argued against sharing in this proceeding primarily because they claim that sharing 5.9 GHz spectrum with unlicensed operations would undermine critical safety-of-life services.[10] However, many services that the DSRC industry plans to offer have nothing to

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6 *Id.* at 12-13.

7 *See id.* at 14.

8 *Public Notice* at 7.

9 Technical Appendix at 14.

10 *See, e.g.* Comments of Intelligent Transportation Society of America at 2-3, ET Docket No. 13-49 (filed May 28, 2013); Comments of the Toyota Motor Corporation at 15-16, ET Docket No. 13-49 (filed May 28, 2013); Comments of American Association of State Highway & Transportation Officials at 10-11, ET Docket No. 13-49 (filed May 28, 2013); Letter from John D. Porcari, U.S. Dep’t of Transp. to Lawrence Strickling, Assistant Secretary for Commc’ns and Information, U.S. Dep’t of Commerce, at 4-5 (May 16, 2013) (attached to Letter from Karl Nebbia, Associate Administrator, Office of Spectrum

do with protecting lives. Instead, many of the planned services consist of ordinary ways for Americans to communicate with one another, pay for goods and services rendered, and keep themselves entertained on the road.

As the Commission recognizes in the *Public Notice*, applications such as "entertainment, social media, maps, and parking . . . are not safety-related."[11] Indeed, as many commenters pointed out in response to NHTSA's advance notice of proposed rulemaking, service providers already offer many of the applications planned for DSRC using non-DSRC spectrum and standards.[12] Nevertheless, DoT has suggested that the 5.9 GHz DSRC service channels could be used for everything from paying tolls,[13] to finding parking spots and paying parking fees,[14] paying at drive-thrus,[15] sending notifications to the driving public about "points of interest,"[16] route guidance and navigation,[17] sending instant messages between vehicles,[18] and even video downloads.[19]

Management, U.S. Dep't of Commerce, to Julius Genachowski, Chairman, FCC, ET Docket No. 13-49 (filed June 10, 2013)).

11 *Public Notice* at 8.

12 *See infra* 17; *see also Public Notice* at 8 (seeking comment on "other spectrum bands, driver assist technologies, and commercial offerings [that] are providing similar services to those envisioned using DSRC.").

13 NAT'L HIGHWAY TRAFFIC & SAFETY ADMIN., *Vehicle Safety Communications Project Task 3 Final Report—Identify Intelligent Vehicle Safety Applications Enabled by DSRC* at 33 (Mar. 2005), http://www.nhtsa.gov/Research/Crash+Avoidance/ci.Vehicle-to-Vehicle+Communications+for+Safety.print.

14 *Id.* at 39.

15 *Id.*

16 *Id.* at 37.

17 *Id.* at 36.

18 *Id.* at 34-35.

19 *Id.* at 39.

Researchers working on Intelligent Transportation Systems (ITS) envision similar non-safety uses for DSRC spectrum. In a presentation for the U.S. Army, an ITS researcher from the University of Michigan-Dearborn listed the following potential DSRC applications:

- Drive thru payment
- Parking lot payment
- "Data transfer/info fueling" (including vehicle computer program updates, map and music data updates, and video uploads)
- Route planning and guidance, and
- Rental car processing.[20]

Similarly, the California Partners for Advanced Transit and Highways (PATH) program at the University of California at Berkeley—a founding member of ITS America and the ITS research program—anticipates that DSRC service channels will be used for "non-safety related data traffic," such as providing "next bus" information for public transit users, or for e-commerce and infotainment.[21]

The auto manufacturers themselves also plan to use the 5.9 GHz band for a variety of non-safety-of-life services. For example, Toyota has suggested that private applications for DSRC spectrum might include fuel/drive-thru management, rental car transaction processing,

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[20] Presentation by Jinhua Guo, Director of Vehicular Networking Systems Research Lab, University of Michigan-Dearborn, 2006 US Army VI Winter Workshop, *Vehicle Safety Communications in DSRC*, at 25 (2006); *see also* Jinhua Guo and Nathan Balon, University of Michigan – Dearborn, *Vehicular Ad Hoc Networks and Dedicated Short-Range Communication*, at 18 (June 26, 2006), http://nathanbalon.net/projects/cis695/vanet_chapter.pdf.

[21] Wei-Bin Zhang, California PATH, University of California at Berkeley, *DSRC and Connected Communications in the 5.8/5.9 GHz Band*, at 5, 22 (Apr. 17, 2012).

and parking management.[22] General Motors (GM) has applied for a patent for using DSRC spectrum to supplement in-car infotainment systems, including by downloading data to smartphones.[23] GM has also applied for a patent for using DSRC spectrum to enable drivers to pay wirelessly at "a fast food restaurant, a parking garage, or a toll booth," and a patent for using DSRC spectrum to enable the delivery of advertisements to vehicles.[24] GM also holds a patent on a method for using DSRC to enable instant chatting applications between vehicles.[25] LG Electronics has filed several patent applications to use DSRC spectrum for settling parking charges[26] and providing traveler information services.[27] Mitsubishi was issued a patent for using

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22 John Kenney, Toyota Info Technology Center, USA, *Dedicated Short Range Communication (DSRC) Applications Tutorial*, at 23 (May 14, 2013), https://mentor.ieee.org/802.11/dcn/13/11-13-0541-01-0wng-dsrc-applications-tutorial.pptx//.

23 GM Global Technology Operations, LLC, *Method and Apparatus for Augmenting Smartphone-Centric In-Car Infotainment System Using Vehicle WiFi/DSRC*, U.S. Patent Appl. No. 13/278,797 (filed Apr. 25, 2013), *available at* https://drive.google.com/viewerng/viewer?url=patentimages.storage.googleapis.com/pdfs/US20130103779.pdf.

24 GM Global Technology Operations, LLC, *Vehicular Wireless Payment Authorization Method*, U.S. Patent Appl. No. 12/631,680 (filed Dec. 4, 2009), *available at* https://drive.google.com/viewerng/viewer?url=patentimages.storage.googleapis.com/pdfs/US20110136429.pdf; GM Global Technology Operations, Inc., *Using V2X In-Network Message Distribution and Processing protocols to Enable Geo-Service Advertisement Applications*, U.S. Patent Appl. No. 12/415,756 (filed Mar. 31, 2009), *available at* https://drive.google.com/viewerng/viewer?url=patentimages.storage.googleapis.com/pdfs/US20100250346.pdf.

25 GM Global Technology Operations, LLC, *Using V2X In-Network Session Maintenance Protocols to Enable Instant Chatting Applications*, U.S. Patent No. 8,032,081 (issued Oct. 4, 2011).

26 LG Electronics Inc., *Apparatus and Method for Settling Parking Charge Using DSRC*, U.S. Patent Appl. No. 09/983,746 (filed Oct. 25, 2001), *available at* https://drive.google.com/viewerng/viewer?url=patentimages.storage.googleapis.com/pdfs/US20020072964.pdf.

27 LG Electronics, Inc., *Information System for a Traveler Information Service and Method for Providing the Service*, U.S. Patent Appl. No. 09/983,747 (filed Oct. 25, 2001), *available at*

DSRC spectrum to provide vehicular communications with roadside services, including for exchanging refueling information and advertisements about available services.[28]

The list of non-safety applications goes on and on. Kia suggests that DSRC will be useful for traffic data, real-time travel information, transit status information, e-payments, and weather updates, just to name a few non-safety applications.[29] Ford anticipates using DSRC for traffic routing and entertainment.[30] In its comments filed before NHTSA, Mercedes-Benz argues that vehicle connectivity should not be limited to safety applications alone, but should also include "[v]alue-added mobility functionalities, such as navigation and traffic aids."[31]

Infineon Technologies, a supplier of semiconductor technologies for transportation applications, describes several potential use cases for a connected vehicle platform, including traffic management, payment applications (tolling and parking), driver assist functions, information services for travel planning and route optimization, software updates over the air, and keyless entry.[32]

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https://drive.google.com/viewerng/viewer?url=patentimages.storage.googleapis.com/pdfs/US6804516.pdf.

[28] Mitsubishi Denki Kabushiki Kaisha, *Vehicle-Roadside Service Providing System, U.S. Patent No. 6,768,934* (issued July 27, 2004), *available at* https://drive.google.com/viewerng/viewer?url=patentimages.storage.googleapis.com/pdfs/US6768934.pdf.

[29] Henry Bzeih, Kia Motors America, *Safety Applications in a Connected Vehicle*, at 13, http://www.in-vehicle-infotainment-summit.com/media/downloads/42-day-2-henry-bzeih-kia-connected-car.pdf (last accessed June 24, 2016).

[30] Mark Hachman, *In the Car with Ford's 'Look Out!' Network: Hands On*, PCMAG (June 2, 2011), http://www.pcmag.com/article2/0,2817,2386340,00.asp.

[31] Letter from Julian Soell, Gen. Manager, Eng'g Servs., Mercedes Benz, to Daniel C. Smith, Senior Assoc. Adm'r for Vehicle Safety, Nat. Highway Traffic Safety Admin., NHTSA Docket No. 2014-0022, at 2 (filed Oct. 20, 2014) (Mercedes Benz NHTSA Comments).

[32] Comments from Infineon Technologies North America Corp., at 3, 8, NHTSA Docket No. 2014-0022 (filed Oct. 20, 2014).

While the transmission of basic safety messages for collision warning purposes may require very low latency and high quality of service, the non-safety related use cases described above do not require such guarantees. Many commenters in NHTSA's proceeding noted that non-safety-of-life DSRC services do not even require the use of DSRC spectrum or protocols, but could be offered instead using other communications protocols like cellular, Wi-Fi, or others. For example, Volvo notes that many DSRC operations that do not require very low latency can be implemented using telematics services such as Car-2-Cloud.[33] General Motors argues that the security certificate communications needed for a vehicle-to-vehicle (V2V) collision-avoidance security system could be provided in a cost-effective and secure manner using existing cellular architecture.[34] Fiat Chrysler states that V2I communications can leverage existing cellular networks rather than DSRC infrastructure that has not yet been deployed, particularly because these communications do not involve time-sensitive messaging.[35] Similarly, Delphi Automotive notes that many V2I communications "are not time-critical" and therefore "may make use of cellular and other wireless technologies."[36] Mercedes-Benz acknowledges that cellular-based communications already provide non-time-sensitive traffic and weather warnings.[37]

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33 Comments of Volvo Cars at 2, NHTSA Docket No. 2014-0022 (filed Oct. 20, 2014).

34 Letter from Brian Latouf, Director, Global Vehicle Safety, General Motors, LLC to Daniel C. Smith, Senior Assoc. Admn'r for Vehicle Safety, Nat. Highway Traffic Safety Admin., NHTSA Docket No. 2014-0022, at 12-16 (filed Oct. 20, 2014).

35 Letter from Stephen L. Williams, Safety, Compliance and Product Analysis, Fiat Chrysler Automobiles, to Daniel C. Smith, Senior Assoc. Admn'r for Vehicle Safety, Nat. Highway Traffic Safety Admin., NHTSA Docket No. 2014-0022, at 2 (filed Oct. 20, 2014).

36 Letter from Ragiemra Amato, Director, Government/Technical Affairs, Delphi Automotive Systems, LLC to Dan Smith et al., Nat. Highway Traffic Safety Admin., NHTSA Docket No. 2014-0022, at Appendix at 5 (filed Oct. 16, 2014).

37 Mercedes Benz NHTSA Comments at 10.

Furthermore, the Pennsylvania Department of Transportation notes that many V2X applications could be provided using Bluetooth, localized Wi-Fi networks, or cellular technology.[38] The Institute of Transportation Engineers acknowledges that some V2I applications—even some safety-adjacent applications, like stop sign warnings—do not require the speed and low latency of DSRC and could be accomplished using cellular technology.[39] The Information Technology & Innovation Foundation (ITIF) states that LTE-A or 5G technologies could work for safety-related applications, and that Wi-Fi might be better suited for some of the proposed non-safety DSRC service channel applications.[40] Finally, the Information Technology Industry Council (ITI) notes that its members are developing a variety of V2V solutions that rely on DSRC, as well as 4G/LTE, 5G, and Wi-Fi.[41] ITI states that 4G/LTE, Wi-Fi and 5G "provide similar capabilities, which could offer many of the same features as DSRC, as well as the potential for broader and faster commercial deployment."[42] Chairman Wheeler has endorsed that view, citing "autonomous vehicles" and "transportation networks" as key 5G benefits.[43] Of course, the issue is not whether auto manufacturers should be engaging in these activities. That is for individual companies and the market to decide. The question is whether the Commission

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[38] Comments of Pennsylvania Department of Transportation at 3, NHTSA Docket No. 2014-0022 (filed Oct. 20, 2014).

[39] Comments of Institute of Transportation Engineers Inc. at 2, NHTSA Docket No. 2014-0022 (filed Oct. 20, 2014).

[40] Comments of ITIF at 6-7, NHTSA Docket No. 2014-0022 (filed Oct. 20, 2014).

[41] ITI Comments to Department of Transportation National Highway Traffic Safety Administration at 2-3, NHTSA Docket No. 2014-0022 (filed Oct. 20, 2014).

[42] *Id.* at 3.

[43] Tom Wheeler, Chairman, Fed. Commc'ns Comm'n, Address at the National Press Club (June 20, 2016), (transcript available at http://www.press.org/sites/default/files/20160620_wheeler.pdf.)

should subsidize these operations by granting exclusive rights to use of 75 megahertz of spectrum for non-safety purposes.

III. THE COMMISSION SHOULD NOT GIVE NON-CRASH-AVOIDANCE DSRC OPERATIONS PRIORITY OVER SIMILARLY-SITUATED NON-DSRC COMPETITORS.

The Commission seeks comment on the "policy reasons for differentiating between safety-of-life and non-safety-of-life applications" in order to assess "what DSRC-related use cases should be expected and permitted in this band."[44] In a spectrum environment characterized by skyrocketing demand, congestion, and scarcity, the Commission and the Administration have rightly concluded that all spectrum users must find ways to use this resource more efficiently, including through sharing. The Commission should conclude at the outset that the non-safety-of-life DSRC operations it permits can and must share equitably with unlicensed users for the following reasons:

(1) Congress and the Commission have long held the view that the primary purpose for granting DSRC companies exclusive use of the 5.9 GHz band is to save lives. In fact, the Commission has noted that many proposed commercial DSRC services could likely operate on an unlicensed basis in the band.

(2) Only a compelling safety purpose—like crash avoidance—justifies a departure from the Commission's policy to maximize efficient use of spectrum through sharing or via auction. Such a compelling purpose is entirely absent with respect to commercial DSRC operations. The Commission has long abandoned the policy of overriding market forces, hampering innovation, and sacrificing efficiency by subsidizing specific companies and technologies with spectrum that is neither shared nor auctioned, without a compelling safety purpose.

(3) The Commission has committed to regulating like services alike, recognizing that such policies foster competition and innovation. Granting non-safety-of-life DSRC services priority in the 5.9 GHz band and requiring the use of a DSRC-specific technical standard, while excluding other entrants that wish to use the band to offer the same services using other standards, violates this important principle.

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44 *Public Notice* at 8.

A. Safety-of-Life Applications, Not the Commercial Applications Now Proposed by Automakers, Led Congress and the Commission to Permit DSRC Licensing.

When it first allocated 5.9 GHz spectrum for DSRC use, the Commission noted that it acted, at least in part, in response to the *Transportation Equity Act for the 21st Century*.[45] In enacting this legislation, Congress found that dedicating additional resources to ITS would "improv[e] transportation safety and efficiency," and noted that a primary goal of ITS is to "achieve[] . . . national transportation safety goals, including the enhancement of safe operation of motor vehicles and nonmotorized vehicles, with particular emphasis on decreasing the number and severity of collisions."[46] The Commission also acted in response to a directive from the National Transportation Safety Board to "[e]xpedite rulemaking action on the allocation of frequencies that would enhance the development possibilities of collision warning systems."[47]

The Commission has repeatedly stressed that the 5.9 GHz frequencies allocated to DSRC are primarily to be used for public safety purposes. In 1999, the Commission noted that ITS services were "expected to improve traveler safety," and that "DSRC applications are a key element in . . . improving the safety of our nation's highways."[48] In its *2004 DSRC Order*, the Commission again noted that the "primary goals of DSRC-based ITS applications are to increase

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[45] *Amendment of Parts 2 and 90 of the Commission's Rules to Allocate the 5.850-5.925 GHz Band to the Mobile Service for Dedicated Short Range Communications of Intelligent Transportation Services*, Report and Order, 14 FCC Rcd 18,221 ¶ 3 (1999) (*1999 DSRC Order*).

[46] *Transportation Equity Act of the 21st Century*, Pub. L. 105-178, §§ 5202(2), 5203(a)(2) (June 9, 1998).

[47] NAT. TRANSP. SAFETY BD., *Safety Recommendation H-95-46* at 5 (Dec. 13, 1995), http://www.ntsb.gov/investigations/AccidentReports/_layouts/ntsb.recsearch/Recommendation.aspx?Rec=H-95-046.

[48] *1999 DSRC Order*, ¶¶ 1, 9.

the safety and efficiency of the nation's surface transportation system"[49] Although the Commission also authorized non-public safety use of the band, it required that "DSRCS communications involving the imminent safety of life—whether by traditional public safety entities, *i.e.*, state and local governments, or by nongovernmental entities, *e.g.*, vehicle-to-vehicle collision avoidance—must have access priority over all other DSRCS communications."[50]

In summary, the primary concern of Congress and the Commission in allocating the 5.9 GHz band for DSRC systems was the use of the band for safety-of-life communications, including V2VSW technology. The Commission rightly granted these communications priority over non-safety-of-life DSRC communications. But even in 1999, the Commission noted that many non-safety-of-life DSRC communications, including some of the applications described above in section II, could likely be offered on an unlicensed basis. Specifically, the Commission stated:

> We believe that low power unlicensed DSRC could benefit some applications, such as fee collection at parking garages and commercial establishments. . . . [W]e believe that these types of applications could be useful for DSRC deployments in the 5.85-5.925 GHz band and we will explore in a future proceeding whether we should provide for such applications under either unlicensed or licensed-by-rule status.[51]

Neither Congress nor the Commission envisioned that the band would be specially reserved for non-safety-of-life DSRC operations or that they would be given priority. Non-safety-of-life DSRC services such as parking, drive-thru payments, and instant messaging between vehicles

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49 *Amendment of the Commission's Rules Regarding Dedicated Short-Range Communication Services in the 5.850-5.925 GHz Band (5.9 GHz Band), Amendment of Parts 2 and 90 of the Commission's Rules to Allocate the 5.850-5.925 GHz Band to the Mobile Service for Dedicated Short Range Communications of Intelligent Transportation Services,* Report and Order, 19 FCC Rcd 2458, 2466-67 ¶ 14 (2004) (*2004 DSRC Order*).

50 *Id.* at 2475 ¶ 32.

51 *1999 DSRC Order*, ¶ 30.

should not be granted priority or exclusive spectrum use over similar services offered using different communications protocols, such as Wi-Fi and Bluetooth.

B. The Commission Should Regulate Similar Services Similarly; Otherwise it Risks Undermining Competition.

The Commission has well-established policies that require it to regulate like services alike and to avoid tilting the playing field in favor of one particular technology. Allowing non-safety-of-life DSRC operations to continue to exclude unlicensed entrants that offer similar types of services, and requiring the use of the DSRC standard to the exclusion of other standards in order to qualify for special spectral privileges, violates both these principles.

The Commission correctly concluded in its *1999 Spectrum Policy Statement* that harmonizing the rules for like services

> provides regulatory neutrality to help establish a level playing field across technologies and thereby foster more effective competition. Such a structure would permit reliance on the marketplace to achieve the highest-valued use of the spectrum. It would also ensure that the Commission and its processes do not become a bottleneck in bringing new radio communications services and technologies to the public.[52]

[52] *Principles for Reallocation of Spectrum to Encourage the Dev. of Telecommunications Technologies for the New Millennium*, Policy Statement, 14 FCC Rcd 19868, 19871 ¶ 9 (1999).

The Commission has applied this principle of regulatory parity in a variety of spectrum contexts, including in the 700 MHz band,[53] the 2.1 and 2.5 GHz bands,[54] and with respect to cellular and PCS licensees,[55] adopting rules intended to treat like services alike.

The Commission allows non-safety-of-life DSRC services to use the 5.9 GHz band on a licensed-by-rule basis and requires that 5.9 GHz users adopt the ASTM standard. At the same time, it has so far declined to allow unlicensed access to the band to offer those same services using a variety of different unlicensed standards, even if they offer identical services. This violates the Commission's policy of regulating like services alike, and its commitment to regulatory parity.

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53 *Reallocation and Service Rules for the 698-746 MHz Spectrum Band (Television Channels 52-59)*, Report and Order, 17 FCC Rcd 1022, 1049 ¶ 62 (2002) ("We continue to believe that regulatory neutrality and operational uniformity across the 700 MHz Band will permit the marketplace to achieve the highest valued end use of the spectrum.").

54 *Amendment of Parts 1, 21, 73, 74 and 101 of the Commission's Rules to Facilitate the Provision of Fixed and Mobile Broadband Access, Educational, and Other Advanced Services in the 2150-2162 and 2500-2690 MHz Bands*, Report and Order and Further Notice of Proposed Rulemaking, 19 FCC Rcd 14165, 14182-83 ¶ 36 (2004) (noting that the band plan adopted must "promote consistent regulatory treatment with similar wireless broadband services" and "offer flexibility through technological neutrality").

55 *Implementation of Sections 3(n) and 332 of the Communications Act Regulatory Treatment of Mobile Services*, Third Report and Order, 9 FCC Rcd 7988 ¶ 6 (1994) ("[W]e determine which reclassified services are 'substantially similar' to existing common carrier services in order to implement the Budget Act requirement that such services be subject to 'comparable' regulation. Second, . . .we revise Part 90 and Part 22 technical and operational rules governing those services to ensure that the rules are, indeed, 'comparable.'")*; see also Implementation of Sections 3(n) and 332 of the Communications Act Regulatory Treatment of Mobile Services*, Second Report and Order, 9 FCC Rcd 1411, 1509 ¶ 263 n.532 (1994) ("By establishing like regulation of substitutable services, the Commission will promote competition. This, in turn, will enable licensees to better serve the communications needs of all wireless consumers and further allow them to maximize the efficient use of their assigned spectrum. A crucial step toward achieving Congress' goal of regulatory parity is the establishment of equal regulation for cellular and PCS licensees.").

As noted in section II above, unlicensed technologies like Wi-Fi and Bluetooth are already used or could be used to provide many of the same commercial services proposed for the 5.9 GHz service channels. Yet the Commission allows only DSRC users operating under the ASTM standard to use the band, giving those providers an effective monopoly through regulation.[56] To facilitate competition in the provision of these like services, the Commission should not favor DSRC with a virtually exclusive grant of spectrum while excluding unlicensed users. Instead, it should treat like services alike.

IV. RECHANNELIZING U-NII-4 STRIKES THE RIGHT BALANCE BY PROTECTING DSRC CRASH-AVOIDANCE AND PERMITTING COMMERCIALLY VIABLE WI-FI.

The Commission requests comment on the merits of proposed sharing approaches. It asks whether an approach "minimize[s] the risks of interference to DSRC more effectively while providing a comparable degree of meaningful access to spectrum for unlicensed devices."[57] Rechannelizing U-NII-4 to designate the top of the band for crash-avoidance best serves this goal. The 5.9 GHz band is, by far, the best near term opportunity for the Commission to meet demand for unlicensed broadband spectrum, and rechannelization will provide appropriate protection for safety-of-life DSRC systems while enabling a sharing approach that permits Wi-Fi to operate in a commercially viable manner. Rechannelization would also make the Commission's rules more consistent with international plans to use the 5.9 GHz band. Cisco's sense and avoid proposal, by contrast, is sharing in name only. It would unnecessarily impose far more onerous restrictions on Wi-Fi consumers, including technical rules that would render commercial Wi-Fi operations unviable.

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[56] *See* 47 C.F.R. §§ 90.379, 95.1509.

[57] *Public Notice* at 7.

A. The 5.9 GHz Band Is by Far the Best Opportunity in the U.S. for Additional Unlicensed Spectrum.

The Commission began this proceeding with the recognition that the already substantial demand for wireless broadband services "is expected to grow significantly," and that additional unlicensed access to 5 GHz spectrum "hold[s] significant promise for helping to accommodate the needs of businesses and consumers for fixed and mobile broadband communications."[58] There is simply no band that will provide a better near-term sharing opportunity than U-NII-4 or that could add more value to the U.S. economy through sharing with unlicensed operations.

Wi-Fi and other unlicensed operations have indisputably created billions of dollars of economic value, along with well-recognized consumer benefits. In 2013 alone, Wi-Fi and related technologies generated $222 billion in economic surplus.[59] Analysts predict that this contribution will grow in 2017 to more than $500 billion in economic surplus and nearly $50 billion in additional GDP.[60] But as the Commission has recognized, that growth will depend on adequate spectrum resources. Three years ago, exhaustion of the 2.4 GHz band, the primary band used for Wi-Fi, was imminent.[61] Now, the effects of saturation have begun. If Wi-Fi is

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58 *Revision in Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5GHz Band,* Notice of Proposed Rulemaking, 28 FCC Rcd 1769, 1774 ¶ 15 (2013) (*2013 NPRM*).

59 Raul L. Katz, Telecom Advisory Services, LLC, *Final Report: Assessment of the Economic Value of Unlicensed Spectrum in the United States*, at 72 (Feb. 2014), http://www.wififorward.org/wp-content/uploads/2014/01/Value-of-Unlicensed-Spectrum-to-the-US-Economy-Full-Report.pdf.

60 Raul L. Katz, Telecom Advisory Services, LLC, *The Future Economic Value of Unlicensed Spectrum*, at 15 (Sept. 11, 2014), http://www.teleadvs.com/wp-content/uploads/Future_Value_of_unlicensed_spectrum.pdf.

61 Rob Alderfer, CableLabs, *WiFi Spectrum: Exhaust Looms*, at 7-8 (May 28, 2013) (citing Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2011-2016).

going to continue to carry exploding amounts of internet traffic, the Commission must act rapidly to provide access to spectrum that enables new higher-capacity channels.[62]

The 5.9 GHz U-NII-4 band represents the best opportunity to meet that need. The 5 GHz band is the only band that is capable of providing multi-gigabit Wi-Fi using spectrally efficient 160 megahertz-wide channels under the current IEEE standard.[63] Because it is adjacent to the workhorse U-NII-3 band, where the Commission's existing service rules have already resulted in substantial Wi-Fi deployments, enabling unlicensed access in the 5.9 GHz U-NII-4 band under reasonable operating rules will allow consumers and business to deploy services that can take advantage of a contiguous 160 megahertz Wi-Fi channel.

Importantly, this would be the *only* contiguous 160 megahertz channel in the band that is not hamstrung by U-NII-2 Dynamic Frequency Selection (DFS) requirements. As NCTA previously has explained, DFS undermines the utility of many Wi-Fi operations by creating complexity, delays, and service gaps that undermine consumers' broadband experience, and by making network equipment more expensive.[64] Accordingly, bands with DFS requirements are far less suitable for the development of carrier-grade consumer Wi-Fi networks. That means that, as a practical matter, access to U-NII-4 under reasonable operating parameters is the only way to provide access to a 160 megahertz channel in the U-NII bands that could be used effectively for outdoor gigabit Wi-Fi deployments.

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62 *See Cisco Visual Networking Index: The Zettabyte Era—Trends and Analysis, 2015-2020*, CISCO (June 2, 2016), http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/vni-hyperconnectivity-wp.html (explaining that wired devices will account for only 34 percent of IP traffic by 2020).

63 *See 2013 NPRM* at 1775-76 ¶ 19.

64 *See* Comments of the National Cable & Telecommunications Association at 20, ET Docket No. 13-49 (May 28, 2013) (describing the challenges created by DFS).

B. Rechannelization Provides the Strongest Protection for Crash-Avoidance and Related DSRC Applications and Enables Commercially Viable Sharing with Non-Safety Uses in the Remainder of the Band.

The Commission can most efficiently and effectively maximize the use of the U-NII-4 band by adopting a rechannelization proposal that grants DSRC licensees exclusive use of one portion of the band to deliver crash-avoidance and related safety-of-life services, while permitting flexible use of the remainder of the band by other DSRC services and unlicensed operations. Although doing so would completely foreclose access to 30 megahertz of 5 GHz spectrum in U-NII-4 for unlicensed operations, it would produce the most complete protection of crash-avoidance applications while ensuring that non-safety-of-life DSRC and Wi-Fi operations have shared access to the remaining spectrum. This plan also has the virtue of complying with the principles of spectrum sharing and regulatory parity outlined above.

Providing dedicated channels for crash avoidance, while allowing other DSRC and Wi-Fi services to coexist in the remainder of the band, offers several advantages. *First,* it would provide for the quietest spectral environment for V2V BSMs and other public safety services. Wi-Fi can successfully share spectrum with many incumbents, and will not cause harmful interference to licensees. But given that DSRC interests have now asserted that the technologies they plan to use cannot operate even in the *existing* U-NII-4 spectral environment using channel 172, rechannelization is the best means of protecting their systems.[65] With exclusive spectrum, even the most sensitive V2VSW signals would have no possibility of co-channel interference issues, aside from DSRC self-interference and those that V2VSW systems already must address

[65] *See* Petition for Reconsideration of the Association of Global Automakers, Inc. and the Alliance of Automobile Manufacturers at 15, ET Docket No. 13-49 (filed May 6, 2016); Opposition of the National Cable & Telecommunications Association to the Alliance of Global Automakers, Inc. and the Alliance of Automobile Manufacturers' Petition for Reconsideration at 14, ET Docket No. 13-49 (filed Jun. 23, 2016).

with respect to U.S. government radar and international fixed satellite service (FSS) operations in the band.

Second, providing a subset of the 75 megahertz of spectrum currently allocated for DSRC for the exclusive use of V2VSW would not compromise the integrity of these operations. As noted above, V2VSW operations require no more than 10 megahertz of spectrum, and 30 megahertz of spectrum is more than sufficient to accommodate both these and all current and planned V2I "safety-adjacent" applications.[66] Moreover, separating V2VSW and other safety-related applications and placing them nearer to the upper band edge would not create additional risk of harmful interference.[67] Importantly, existing DSRC safety channels already must address cross-channel interference from other DSRC operations and out-of-band emissions from existing adjacent Wi-Fi and FSS deployments.[68] Moving the BSM channel to the top of the band would not materially alter the range of interference risks, and instead could provide an opportunity to build-in new interference protections.[69]

Third, non-safety-of-life operations can—and should—easily coexist on the same channels as Wi-Fi in the remainder of the band on equal regulatory footing. Even the non-safety of-life ("safety-adjacent") services that the DSRC community envisions will rely on V2I communications in the future do not require the same quality-of-service guarantees as V2VSW operations.[70] And certainly, as discussed in section II above, the purely commercial services

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[66] *See supra* at 4-5.

[67] *See* Letter from Broadcom to Marlene H. Dortch, Secretary, FCC at Attachment 5-6 (May 5, 2016); *see also* Technical Appendix at 15-16.

[68] Technical Appendix at 16-18.

[69] *See* Letter from Broadcom, *supra* note 67.

[70] *See supra* Section II. B.

planned for the DSRC service channels have no such latency or service requirements, and also do not justify any special interference privileges from the Commission. In other words, although DSRC interests insist that V2VSW technologies require high availability and low latency in order to function optimally, non-V2VSW operations—and especially commercial DSRC operations—do not have the same quality of service requirements, should not benefit from the extraordinary government subsidy of a free exclusive license, and can share the band with other users.

C. The Existing U-NII-4 Channel Plan is Inconsistent with International Plans for the 5.9 GHz Band.

The Commission seeks comment on whether its existing DSRC band plan and the sharing proposals "match up with international efforts for safety-related DSRC systems."[71] International developments support the conclusion that rechannelization offers the best approach to sharing in the 5.9 GHz band. For example, European regulators concluded that 30 megahertz is sufficient for DSRC safety functions—20 megahertz for "time critical road safety applications" and an additional 10 megahertz for non-time critical safety operations.[72] The Electronic Communication Committee of the European Conference of Postal and Telecommunications Administrations (CEPT) has adopted an overall allocation from 5855 to 5925 megahertz for intelligent transportation systems—similar to the U.S. allocation. Importantly, however, the EU allocation already concentrates safety-related functions at 5875 to 5905 megahertz, a recognition

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[71] *Public Notice* at 8.

[72] *See* Michael A. Calabrese, The Open Technology Institute at New America, *Spectrum Silos to Gigabit Wi-Fi*, at 27-28 (Jan. 2016) (Spectrum Silos); *see also* John Harding et al., NAT'L HIGHWAY TRAFFIC & SAFETY ADMIN., *Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application*, at 117 (Aug. 2014) (V2V Report).

that safety applications do not require the full 75 megahertz.[73] Rechannelization is consistent with this approach, grouping and protecting safety-related functions while facilitating sharing in the rest of the band.

Nor is international harmonization a barrier to rechannelization even in jurisdictions that have adopted different channelization schemes. As in the United States, safety-related DSRC has yet to be deployed in the 5.9 GHz band in any meaningful way in other countries.[74] But when (and if) V2V technologies are eventually deployed, they will likely operate primarily on shared spectrum because other countries have focused their efforts in the 5 GHz band on expanding spectrum available to Wi-Fi and other similar radio local area network (RLAN) technologies. In fact, WRC-19 agenda item 1.16 requires the study of the 5.9 GHz band for RLANs' use internationally,[75] meaning that the U.S. could well be left behind if it abandons its policies favoring spectrum sharing and requires unlicensed operations to sense and avoid even non-safety DSRC traffic.[76]

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73 *See* 2008 O.J. (L 220) 24, http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32008D0671. The 20 megahertz below this band is allocated to non-safety ITS applications, and the 20 megahertz above is reserved for future consideration of an ITS extension. *See* Spectrum Silos at 28.

74 *See, e.g.*, Contribution to WRC-19 AI 1.12, *Information on Status of Intelligent Transportation Systems Standardization in Europe and Worldwide* (received May 2, 2016). In Japan, where some deployment has occurred, neither the ITS spectrum allocation nor standards are harmonized with the United States or Europe.

75 *See* World Radio Communication Conference, *Agenda for the World Radiocommunication Conference 2019*, Resolution 809 (WRC-15), https://www.itu.int/dms_pub/itu-r/oth/0c/0a/R0C0A00000C0027PDFE.pdf. In contrast, WRC study item 1.12, which focuses on intelligent transportation systems, identifies no spectrum at all for international study.

76 For example, Ofcom, which regulates spectrum use in the United Kingdom, has argued in ITU proceedings for greater access to the 5 GHz band for Wi-Fi. *See* Contribution of United Kingdom of Great Britain to Working Party 5A, WRC-19 A1 1.16 (May 2, 2016). Ofcom has also opened up a 5 GHz consultation for their own domestic purposes, which includes proposing to open 5.9 GHz. *See* OFCOM, *Improving spectrum access for consumers in the 5*

D. Cisco's "Sense-and-Avoid" Proposal is Sharing in Name Only and Would Drastically and Unnecessarily Limit Unlicensed Access Even for Non-Safety DSRC Operations.

In contrast to the rechannelization approach, Cisco envisions a sharing regime that would require U-NII-4 devices to monitor all DSRC operations between 5855 and 5905 MHz and cease transmitting across the entire U-NII-4 band and the top 25 megahertz of the U-NII-3 band for one second if a DSRC signal is detected anywhere in those 50 megahertz of spectrum.[77] And in most of the U-NII-4 band, automotive interests have argued that the sense-and-avoid proposal should require U-NII devices to detect DSRC signals at very faint levels. Moreover, Cisco's proposal would require U-NII devices to vacate the entire band in order to make way for commercial and other non-safety-of-life traffic that may only be using one channel in the band. That could mean that if a Wi-Fi device senses a single faint DSRC signal on a single 10 megahertz channel, it must avoid the entire 75 megahertz—even if the rest of the band is completely empty.

This proposal would permit "sharing" in name only. In reality it would be a poison pill for commercial Wi-Fi operations in the band. Cisco's approach is unworkable for several reasons. *First*, it requires U-NII-4 devices to vacate portions of the band that DSRC is not even using, effectively granting DSRC operations a very large guard band without any analysis of how much, if any, guard band is actually needed between DSRC and U-NII operations. In fact, the proposal itself makes clear that it would provide far more protection than DSRC actually

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GHz band (May 13, 2016), http://stakeholders.ofcom.org.uk/binaries/consultations/5-GHz-Wi-Fi/summary/improving-spectrum-access-consumers-5GHz.pdf.

[77] Letter from Mary L. Brown, Senior Director, Government Affairs, Cisco Systems, Inc., to Marlene H. Dortch, Secretary, FCC, ET Docket No. 13-49, Attachment at 4-5 (filed Dec. 23, 2015).

needs: it would, in effect, provide a *70 megahertz* guard band between existing U-NII-3 operations and DSRC channel 180, for example, but a 30 megahertz guard band for channel 172.[78] Both of these represent far more spectral isolation than DSRC needs in order to function reliably. Indeed, DSRC proponents seek no guard band at all between adjacent DSRC channels, and have no guard band between DSRC operations and in-band satellite and government operations. The huge and unexplained difference between these levels of protection makes clear that this approach was not designed with efficient or workable sharing as the real goal.

Second, Cisco's proposal provides significantly more *temporal* isolation than necessary. The proposal would require U-NII devices to vacate the entire band for one second if a DSRC signal is detected.[79] But time critical, safety-of-life DSRC messages last far less than one second. In fact, a DSRC basic safety message will typically be transmitted once every 100 *milli*seconds,[80] and the duration of the actual message is far shorter still. Unlike potential commercial applications of DSRC technology, truly time critical safety-of-life applications will, by definition, not involve extended periods of intensive data exchange with durations measured in seconds. Accordingly, Cisco's proposal will unnecessarily restrict the time intensity of spectrum use in the U-NII-4 band as well as its spectral intensity.

Third, Cisco's proposal does not distinguish between different types of DSRC signals. As the record confirms,[81] many planned DSRC applications are not time sensitive, and have

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78 *See id*.

79 *Id.* at 5.

80 *See, e.g.*, SAE International, *Surface Vehicle Standard: Dedicated Short Range Communications (DSRC) Message Set Dictionary* § 5.2 (Mar. 2016); Crash Avoidance Metrics Partnership, *Vehicle-to-Vehicle Safety System and Vehicle Build for Safety Pilot (V2V-SP) Final Report*, *Volume 2 of 2: Performance Testing*, at 6 (Apr. 10, 2014).

81 *See supra* Section II. B.

nothing to do with safety. Many will support *commercial* applications such as ordering fast food and downloading movies. In fact, such data may ultimately constitute the majority of DSRC spectrum use. Nonetheless, the Cisco proposal would preclude Wi-Fi that senses a DSRC radio signal ordering a Big Mac in exactly the same manner as one sending a safety message. Recognizing this problem, the Commission seeks comment on distinctions between safety and non-safety DSRC applications.[82] Cisco's proposal, however, does not provide any mechanism whatsoever for distinguishing between types of DSRC traffic. Therefore, it would not only result in less efficient use of the U-NII-4 band, but much of this efficiency would result from sensing and avoiding commercial and other non-safety signals. While there may be policy reasons for prioritizing crash-avoidance traffic, there is no legal or policy basis for prioritizing commercial DSRC traffic over all other uses.[83]

V. THE COMMISSION SHOULD MODIFY ITS DRAFT TEST PLAN TO PRODUCE A RELIABLE ANALYSIS OF WI-FI/DSRC SHARING.

The Commission's test plan represents a unique opportunity to provide sound technical information that will inform the Commission's efforts to maximize efficient use of the U-NII-4 band. In the *Public Notice* the Commission seeks comments on the test plan it is devising, which will "complement[], but remain[] independent of" the August 2015 test plan proposed by the DoT.[84] To achieve the full potential of the 5.9 GHz band, the Commission should augment its existing test plan proposals to enable policymakers to move beyond various interference-related characterizations and provide a basis for a more reliable understanding of DSRC safety system

82 *See Public Notice* at 8.

83 *See supra* Section II. B.

84 *See Public Notice* at 10.

efficacy in a shared spectrum environment. In addition, the Commission should not impose specific form factor or other requirements on DSRC and unlicensed broadband equipment used for lab and field testing.

A. The Commission Should Carefully Design Tests That Will Produce Actionable Data about DSRC Safety System Efficacy in a Shared Spectrum Environment.

The *Public Notice* explains that the Commission intends "to collect the relevant empirical data for use in analyzing and quantifying the interference potential introduced to DSRC receivers from unlicensed transmitters operating simultaneously in the 5.850-5.925 GHz band."[85] To do so, the draft test plan envisions taking measurements relating to the radio frequency environment, channel quality, and other specific interference-related characteristics of the DSRC-Wi-Fi interaction.[86] While these measurements would be useful, the Commission should extend the procedures in the draft test plan to achieve a full understanding of the impact of Wi-Fi sharing on DSRC performance. To that end, the Commission should:

1. Focus on the provision of basic safety messages, which contain all relevant information to provide safety warnings between vehicles, and are the only messages that would be mandated by the pending NHTSA rulemaking.

2. Test both rechannelization and Cisco's proposed approach to sharing as well as any hybrid approaches for which prototypes are made available.[87]

3. Investigate the effect on DSRC performance of co-primary systems, including federal radar systems and commercial FSS.

4. Measure actual DSRC system efficacy, such as the provision of specific and timely driver warnings to successfully avoid collisions.

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[85] *Id.* at 11.

[86] *See generally id.* at Attachment, Draft Test Plan.

[87] Comments of Qualcomm Incorporated, ET Docket No. 13-49 at 8-16 (filed May 28, 2013).

1. The Test Plan Should Focus on the Provision of Basic Safety Messages.

BSMs are the core safety transmissions in V2V communications. As such, BSMs are the central function of the DSRC safety system, and the only transmissions that NHTSA is considering mandating in its pending rulemaking. They are also the only well-defined type of DSRC transmission. Other possible DSRC services are ancillary and, even after seventeen years, are not fully developed.[88] Any testing of non-BSM transmissions would be conjectural and unreliable. The Commission's measurement system should, therefore, focus on BSM performance.

DSRC systems provide V2V safety warning services in a single dedicated 10 megahertz channel in order to increase the reliability of transmissions.[89] Use cases can involve communications between vehicles moving at high relative velocity, and safety warnings must be delivered in a timely fashion. The use of a single channel for this service ensures that all vehicles are tuned to the same frequency to exchange information.

This V2V information exchange occurs through BSMs. BSMs contain all relevant information to provide safety warnings between vehicles, such as geographic coordinates, heading, acceleration, and other key information summarized in Table 1.

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[88] *See* Technical Appendix at 10 ("A variety of other services have been envisioned by DSRC stakeholders, though these services are generally ancillary to NHTSA's core interest in V2V safety and are at an even more nascent stage of development.").

[89] *See id.* at 5.

Table 1: Contents of Basic Safety Messages[90]

Table V-1 Contents of BSM Part I[140]

Part I	
Data Frame (DF)	**Data Element (DE)**
Position (DF)	
	Latitude*
	Elevation*
	Longitude*
	Positional accuracy*
Motion (DF)	
	Transmission state*
	Speed
	Steering wheel angle
	Heading*
	Longitudinal acceleration*
	Vertical acceleration
	Lateral acceleration
	Yaw rate*
	Brake applied status
	Traction control state
	Stability control status
	Auxiliary brake status
	Brake status not available
	Antilock brake status
	Brake boost applied
Vehicle size (DF)	
	Vehicle width
	Vehicle length
	*Required in Safety Pilot Model Deployment

In addition to V2V BSMs, DSRC interests envision a variety of other services, though these services are generally ancillary to the NHTSA's core interest in V2V safety and are at such

90 V2V Report, *supra* note 72, at 75. Note that the "Part I" data elements shown in the figure are mandatory in every BSM. "Part II" data such as path history and vehicle identity (among many others), not shown in the figure, are employed in BSMs only when necessary during specific events.

an early stage of development that testing them would produce unreliable guesswork.[91] Within the DSRC system architecture, a control channel advertises and manages access to these services, and DSRC systems can provide these services on the other DSRC channels, as well as the service interval of the control channel.[92]

The NHTSA research report on this issue notes that a two-radio solution is preferable for DSRC implementations.[93] A single radio solution would require time division of DSRC services between a control interval and a service interval, with BSMs transmitted during the control interval. Combined with a small guard interval to space the transmissions, a single radio solution therefore would reduce BSM capacity to 46 percent, relative to a dedicated BSM radio.[94] NHTSA therefore correctly prioritizes the core V2V safety applications over other DSRC services by recommending a two-radio solution that enables dedicated BSM transmissions.

In a two-radio approach, non-V2V services will continue to operate on a time division basis. The IEEE 1609.4 standard divides DSRC transmissions into 100 millisecond intervals, alternating between the control channel and service channels for 50 milliseconds at a time.[95] All DSRC functions outside of BSM safety warnings will be subject to this time division—checking the control channel for services, then switching to the relevant service channel to utilize the desired service. As NHTSA notes, this time division inherently reduces the capacity available.[96] The logic of the DSRC protocol therefore regards all services that are not BSM safety warnings

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91 *See supra* Section II.

92 IEEE Standard, *1609.4-2016 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Multi-Channel Operation* (IEEE STANDARDS ASS'N 2016).

93 V2V Report at 94.

94 *Id.* at 95-96.

95 *See* IEEE Standard 1609.4-2016, *supra* note 92; V2V Report at 94.

96 V2V Report at 94.

as a secondary priority, since such data and services are allocated less time in the system architecture.

Testing only this architecture makes sense from the perspective of the primary governmental interest in road safety and also from the perspective of the lesser performance needs of non-BSM services. Indeed, NHTSA is cautious in its views toward V2I applications, noting that V2V BSM service "should not be compromised due to broadcasting more data for V2I."[97] In light of these facts, the Commission should focus the test plan on the core governmental interest of BSM communication in V2V and on how to best enable spectrum sharing in U-NII-4 while advancing the core safety function of DSRC.

2. The Test Plan Should Investigate Multiple Sharing Approaches.

Spectrum sharing solutions are likely to arise from modification of both Wi-Fi and DSRC operations that take advantage of their common 802.11 protocol infrastructure to produce robust compatibility. Specifically, the test plan should examine:

- ***Rechannelization of the DSRC band plan to enable exclusive channel access for BSMs.*** The test plan should investigate DSRC safety efficacy under adjacent channel interference from Wi-Fi, with BSMs operating on channels 180, 182, and 184, with the different Wi-Fi channel bandwidths, power levels, and deployment scenarios already specified. Performance under these conditions can be compared to DSRC baseline performance, modified as suggested in this document, to analyze the efficacy of rechannelizing DSRC for spectrum sharing purposes.

- ***Vacation of only active DSRC channels.*** The test plan should examine the spectral mask that would be required for Wi-Fi to protect only the DSRC channel in which it has sensed critical safety activity (i.e., BSMs). This would enable Wi-Fi to continue using the 5.9 GHz band in channels where it has not sensed such activity. If the mask required to maintain DSRC safety efficacy is too costly or tight, adjacent channel and second adjacent channel bandwidth deferment can also be explored. The Commission should also study time-based Wi-Fi modifications as needed, including the defer period and the maximum Wi-Fi transmission time. The Commission should select a range of values for study that maintain DSRC BSM performance while enabling robust sharing of the 5.9

[97] *Id.* at 33.

GHz band. By testing a range of parameters, the test plan may find the right formulation to enable DSRC safety system efficacy while maximizing Wi-Fi utility for consumers.

- ***Modification of the DSRC protocol to send acknowledgement signals that Wi-Fi systems may use to guide DSRC avoidance***. Investigation of this approach to sharing the 5.9 GHz band should include the frequency at which acknowledgements must be sent to enable continued efficacy of DSRC.

3. The Test Plan Should Investigate the Effect of Co-Primary Systems.

In the *Public Notice* the Commission appropriately notes that other users of the spectrum may impact DSRC operations, in-band and adjacent-band, federal and commercial, and even DSRC itself.[98] These include commercial FSS ground stations, federal radars, and Wi-Fi devices. These systems exist today and have been in place for years. Therefore, DSRC must account for their presence in its system design. Recognizing this, it is imperative that the test plan incorporate the impact of these systems in measurements of the baseline performance of DSRC. As written, the test plan will simply measure background noise levels associated with Wi-Fi devices, excluding other incumbent systems, and baseline measurements of DSRC will be taken in an interference-free environment.[99] Without accounting for the other systems active in the band, a realistic baseline of DSRC performance is not possible. DSRC licensees must have designed their systems to withstand the signals of the other U-NII-4 incumbents. It would be unreasonable to expect that engineers designed safety systems that would suffer harmful interference in the presence of satellite and government systems known to operate co-channel. Understanding how DSRC systems avoid harmful interference from these systems will provide the Commission with important information as it seeks an effective sharing solution.

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[98] *Public Notice* at 8.

[99] *See* Draft Test Plan § 2.3.

4. The Test Plan Should Measure Real-World DSRC Safety Efficacy.

While the Commission's proposed testing will collect a number of technical measurements relating to DSRC operation, such as packet error rate, noise floor, and other data, there is no proposed measurement of the *actual outcomes* of DSRC performance.[100] This omission is a consequential one: *the existing draft test plan would provide no framework for the Commission to understand real-world DSRC safety performance outcomes and how they may be affected by sharing*.

Testing should, therefore, measure actual DSRC safety efficacy by examining the timely delivery of specific safety warnings enabled by BSMs and the likelihood of their success in achieving collision avoidance. This can be accomplished through tests that program the six safety messages enabled by BSMs, shown in Table 2 below.

Table 2: V2V Safety Warnings Enabled by BSMs[101]

Warning	***Purpose***
Emergency Electronic Brake Lights (EEBL)	Broadcasts "hard braking" messages to surrounding vehicles.
Forward Collision Warning (FCW)	Warns the driver of a possible collision with a vehicle ahead, traveling in the same direction.
Blind Spot Warning / Lane Change Warning (BSW / LCW)	Provides a warning when a vehicle occupies the driver's blind spot.
Do Not Pass Warning (DNPW)	Warns a passing driver when a vehicle cannot safely be passed.
Intersection Movement Assist (IMA)	Warns a driver when it is not safe to enter an intersection due to the presence of other vehicles.
Left Turn Assist (LTA)	Warns a driver not to turn left due to an approaching vehicle.

[100] *See id.* § 2.1.

[101] *See* V2V Report at 120.

The Commission also can make the scope of tests more efficient by focusing on the warnings that NHTSA has said are unique to DSRC—Intersection Movement Assist and Left Turn Assist.[102] Other warnings are also supported by other technologies, and this redundancy makes a technical investigation less crucial.

In addition, the Commission should test DSRC efficacy when two DSRC radios are operating in the same vehicle, and not just with a single radio unrealistically transmitting and receiving basic safety messages in isolation. As NHTSA has explained, "at a minimum, V2V devices would require two DSRC radios."[103] In the real world, these two radios, operating on different channels, will be necessary to simultaneously monitor the designated safety channel and perform other DSRC functions.[104] Testing with only a single DSRC radio, therefore, could substantially overestimate the baseline efficacy of DSRC by failing to measure adjacent-channel DSRC self-interference.

Testing the performance of safety warnings under realistic conditions, on the other hand, can provide the necessary foundation for understanding the baseline performance of the DSRC system, accounting for its design and environment, as well as the impact of spectrum sharing approaches. The method for this analysis should include the successful delivery of warnings, accounting for human reaction time and the braking distance required at various speeds.

Significantly, researchers have already provided a framework for this analysis.[105] Paul Alexander *et al.* calculated the avoidance range requirement—the distance required to bring a

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[102] *See id.* at 20.

[103] *Id.* at 67.

[104] *Id.* at 219.

[105] Paul Alexander, David Haley, and Alex Grant, *Cooperative Intelligent Transportation Systems: 5.9-GHz Field Trials*, PROCEEDINGS OF THE IEEE, July 2011.

vehicle to a stop from a given speed—using human reaction time and braking distances taken from the journal of Transportation Human Factors, as well as the American Association of State Highway and Transportation Officials and the Federal Motor Carrier Safety Administration. Their method enabled analysis of the success of DSRC in delivering specific safety messages within the time frame required to produce human reactions leading to collision avoidance. This, of course, is the central aim of DSRC.

The Commission should also further bolster this outcome-focused assessment method by constructing a risk-based analysis. Rather than analyzing unrepresentative corner cases, testing should focus on the actual harms likely to arise, rather than unrealistic theoretical harms. To do so, the test plan should use its research observations to assess how any effect on DSRC safety functions would manifest in the market as a function of likely DSRC adoption, contention with other services, human factors, and other elements.[106]

The final test plan should rely on this type of objective metric for system performance, and should assess this data based on likely real-world manifestations. Collecting a variety of technical data points, as currently envisioned in the draft test plan, is useful but insufficient in determining the feasibility of different approaches to spectrum sharing.

B. The Commission Should Not Impose Specific Form Factor or Other Requirements on Test Devices.

To facilitate testing, the Commission also asks parties to submit “prototype unlicensed, interference-avoiding devices” to be used in testing.[107] Although the *Public Notice* refers to the

[106] For a review of risk-informed spectrum policy, *see* Jean Pierre de Vries, University of Colorado, Boulder, *Risk-Informed Interference Assessment: A Quantitative Basis for Spectrum Allocation Decisions*, (Sept. 26, 2015) http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2574459.

[107] *Public Notice* at 10.

"submission of acceptable prototypes," it does not define specific criteria for acceptability.[108] At this stage, as it has done in other sharing tests, the Commission should accept non-miniaturized DSRC and Wi-Fi devices for testing as long as they are able to perform the functions being tested. To do otherwise would cause delay, provide no additional benefit, and would undermine innovation.

As the Commission has recognized, some prototypes are already under development. But DSRC technologies have yet to see any meaningful commercial deployment, and this slow pace of deployment has created uncertainty about when (and if) 5.9 GHz devices designed to share with DSRC will ever have commercial viability. It would, therefore, be unreasonable for the Commission to require either DSRC or Wi-Fi test devices to be miniaturized and reduced to silicon at this early stage in their development. This process is extremely costly and beyond what can reasonably be expected of manufacturers with no guarantee that the miniaturized devices will be marketable. Furthermore, there is often a distinct advantage to testing non-miniaturized devices, which are easier to study and modify to test ranges of test parameters. Accordingly, the Commission should determine that test "prototypes" need only be capable of demonstrating the sharing behavior to be tested.

Moreover, whatever standard the Commission selects for determining the sufficiency of a prototype for testing, it should apply uniformly to unlicensed and DSRC devices. An appropriate test plan that achieves the goals described above requires both DSRC and unlicensed devices in order to accurately demonstrate sharing performance under all the proposals to be considered, including rechannelization. Any standard the Commission adopts to determine "acceptable prototypes" should therefore apply equitably to both technologies.

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[108] *See id.*

VI. CONCLUSION.

NCTA strongly supports the Commission's efforts to update and refresh the record on U-NII-4, which represents the best near-term opportunity to meet the demand for fast and ubiquitous Wi-Fi. By taking the steps described above, the Commission can promote the continued success of Wi-Fi and other unlicensed broadband uses while, at the same time, protecting crash-avoidance technologies as they continue their development. NCTA looks forward to working with the Commission and DSRC stakeholders to develop a sharing solution that will facilitate unlicensed use of the U-NII-4 band while protecting safety-of-life DSRC operations from harmful interference.

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Technical Appendix

Optimizing DSRC Safety Efficacy and Spectrum Utility in the 5.9 GHz Band

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Abstract

The US Department of Transportation is considering whether road safety would be improved through a mandate of a nascent vehicle-to-vehicle communications technology known as dedicated short-range communications (DSRC). DSRC enjoys a wireless frequency allocation that the Federal Communications Commission has proposed to be shared with new access to Wi-Fi, as part of its ongoing efforts to boost broadband access and economic growth. This paper describes how DSRC safety services can be advanced in a manner that also enables robust sharing of wireless spectrum resources, enabling the government to advance the dual objectives of road safety and economic growth.

About the Authors

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1) Purpose

This paper provides an overview of dedicated short-range communications (DSRC) technology to demonstrate how the safety applications at its core can be optimized in a manner that also enables greater utilization of the 5850-5925 MHz frequency band (also called the 5.9 GHz band, or U-NII-4) by newly permitting Wi-Fi use.[1]

The FCC allocated spectrum for DSRC in the 5.9 GHz band nearly 15 years ago, and the fact that DSRC systems have not yet been deployed provides an opportunity to shape their implementation in a fashion that advances important governmental interests, including both road safety and economic growth. Wi-Fi and DSRC both utilize 802.11 protocols developed by the IEEE, and Wi-Fi has successfully shared spectrum with a variety of other services since its inception. The nascent, formative state of DSRC development enables favorable opportunities to coordinate the operations of the two technologies.

We will outline several specific considerations relating to coexistence between Wi-Fi and DSRC, highlighting important functions of DSRC safety system architecture, including the operation of Basic Safety Messages (BSMs) and other DSRC services. We then use these observations to recommend an implementation approach that optimizes DSRC safety efficacy and Wi-Fi coexistence.

We endeavor to present meaningful technical considerations relating to a potential DSRC mandate. Since DSRC is in pre-deployment state and there are many aspects of implementation planning that remain in flux, we do not present definitive conclusions. Rather, we outline how DSRC can be shaped in a manner that emphasizes safety outcomes and overall spectrum utility.

2) Executive Summary

Through detailed review of DSRC system architecture, we find that the vehicle-to-vehicle (V2V) DSRC safety services that are of primary interest to the National Highway Traffic Safety Administration (NHTSA) are best advanced through a dedicated channel that enables real-time communications. We also find that the inherent system logic of DSRC regards vehicle-to-infrastructure (V2I) services as a secondary priority; such services are also more nascent and uncertain than V2V given their reliance on currently nonexistent roadside infrastructure and, in many cases, their redundancy with other existing technologies.

We therefore conclude that NHTSA's objectives for DSRC can be served through a single 10 megahertz-wide channel. A second 10 megahertz channel may enable the development of real-time V2I safety applications over the longer-term, although it is unclear that such services will be implemented. Depending on the

[1] The Federal Communications Commission has proposed extending the 5 GHz Wi-Fi allocation

tangibility of V2I safety services, a third channel could enable the possibility of their further growth.

In examining the channel plans of Wi-Fi and DSRC, we find an opportunity for coexistence of the two technologies through frequency separation. In particular, the rechannelization of the 5.9 GHz band in accordance with IEEE 802.11ac, the latest wireless networking standard, can provide DSRC with up to 30 megahertz of exclusive-use spectrum in the upper portion of the 5.9 GHz band, more than enough to fully enable the core safety functions of DSRC. By implementing the most critical V2V safety functions of DSRC in this dedicated spectrum, the FCC can ensure robust coexistence between Wi-Fi and DSRC in the remaining portions of the 5.9 GHz band. Through frequency separation, we note that the FCC may also see fit to sacrifice one Wi-Fi channel in order to provide the highest level of protection to the core safety function of DSRC. There is no persuasive evidence to suggest that such a rechannelization would diminish the safety objectives that are central to NHTSA's interest. In fact, this approach would afford the opportunity to make the V2V safety functions of DSRC even more robust.

3) DSRC System Requirements

At the heart of the government's consideration of a potential mandate for DSRC technology is an interest in enhancing road safety through V2V communications. It is therefore important to understand the core system requirements that facilitate this outcome, as well as the broader landscape of road safety technologies.

a) DSRC System Overview

The NHTSA research report[2] outlines the basic aspects of DSRC. As currently envisioned, DSRC consists of a variety of transportation-related communications services, potentially using up to 70 megahertz of spectrum bandwidth. The functions of these services are segmented across 10 megahertz-wide channels, as shown in Figure 1.

[2] National Highway Traffic and Safety Administration, *Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application* (Aug. 2014) ("*V2V Report*").

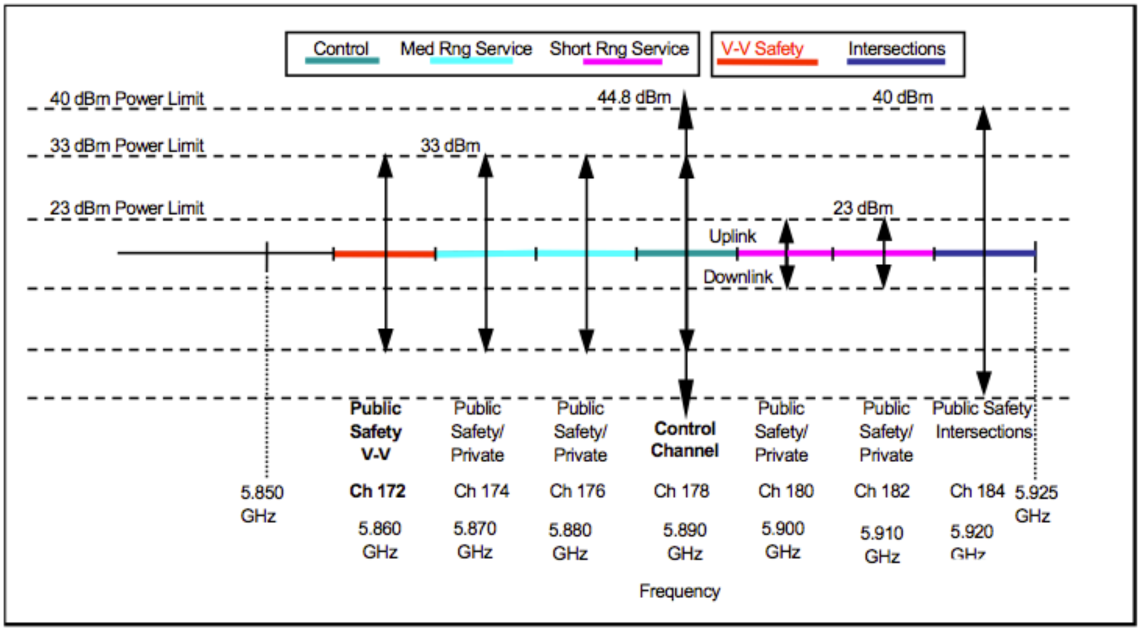

Figure 1: Current DSRC Channel Plan[3]

V2V safety warning services are provided in a single 10 megahertz channel. A central control channel broadcasts the availability of other services, which are provided on the remaining channels.[4]

In light of NHTSA's interest in exploring a potential mandate for V2V technology, we will now explore considerations relating to V2V and other DSRC services.

b) Basic Safety Messages are the Core Function of V2V

V2V safety warning services are provided in a single dedicated 10 megahertz channel in order to increase the reliability of transmissions. Use cases can involve communications between vehicles moving at high relative velocity, and safety warnings must be delivered in a timely fashion. The use of a single channel for this service ensures that all vehicles are tuned to the same frequency to exchange information.

This V2V information exchange occurs through Basic Safety Messages (BSMs). BSMs contain all relevant information to provide safety warnings between vehicles, such as geographic coordinates, heading, acceleration, and other key information summarized in Table 1.

[3] *V2V Report*, p.93.
[4] Assumes a two-radio implementation, which NHTSA has indicated it prefers. Single-radio versus double-radio solutions are discussed in Section 3(c) of this paper.

Table V-1 Contents of BSM Part I[140]

Part I	
Data Frame (DF)	**Data Element (DE)**
Position (DF)	
	Latitude*
	Elevation*
	Longitude*
	Positional accuracy*
Motion (DF)	
	Transmission state*
	Speed
	Steering wheel angle
	Heading*
	Longitudinal acceleration*
	Vertical acceleration
	Lateral acceleration
	Yaw rate*
	Brake applied status
	Traction control state
	Stability control status
	Auxiliary brake status
	Brake status not available
	Antilock brake status
	Brake boost applied
Vehicle size (DF)	
	Vehicle width
	Vehicle length
	*Required in Safety Pilot Model Deployment

Table 1: Contents of Basic Safety Messages[5]

The data elements that make up the contents of BSMs enable specific safety warnings. V2V safety warnings include several specified scenarios, outlined in Table 2.

[5] *V2V Report*, p.75. Note that the "Part I" data elements shown in the figure are mandatory in every BSM. "Part II" data such as path history and vehicle identity (among many others), not shown in the figure, are employed in BSMs only when necessary during specific events. See pp.76-79 of *V2V Report* for a complete list of Part II BSM data elements.

Warning	*Purpose*
Emergency Electronic Brake Lights (EEBL)	Broadcasts “hard braking” messages to surrounding vehicles.
Forward Collision Warning (FCW)	Warns the driver of a possible collision with a vehicle ahead, traveling in the same direction.
Blind Spot Warning / Lane Change Warning (BSW / LCW)	Provides a warning when a vehicle occupies the driver’s blind spot.
Do Not Pass Warning (DNPW)	Warns a passing driver when a vehicle cannot safely be passed.
Intersection Movement Assist (IMA)	Warns a driver when it is not safe to enter an intersection due to the presence of other vehicles.
Left Turn Assist (LTA)	Warns a driver not to turn left due to an approaching vehicle.

Table 2: V2V Safety Warnings Enabled by BSMs[6]

NHTSA notes that IMA and LTA warnings are most likely to be unique to DSRC systems,[7] while other warnings such as BSW and FCW are also supported by other technologies.

NHTSA has indicated that it is unlikely to adopt specific mandates for V2V safety warning support;[8] therefore, the implementation of safety warnings is dependent on their adoption by original equipment manufacturers (OEMs). However, support for safety warnings is likely to be uneven across manufacturers, and some warnings that NHTSA views as unique to DSRC, such as LTA, may be scarcely supported. Table 3 outlines the current plans for support for safety warnings among major OEMs.

[6] See *V2V Report*, p.120.
[7] As reflected in NHTSA’s cost and benefits analysis. See, e.g., *V2V Report*, p.259.
[8] Federal Motor Vehicle Safety Standards: Vehicle-to-Vehicle (V2V) Communications, 79 Fed. Reg. 49,270, 49,272 ¶ 13 (proposed Aug. 20, 2014) (to be codified at 49 C.F.R. pt. 571) (“ANPRM”).

OEM/Applications	Ford	GM	Honda	Mercedes	Toyota	Hyundai-Kia	Nissan	VW-Audi
EEBL	X	X	X	X	X			X
FCW	X	X	X	X		X	X	X
BSW / LCW	X	X	X	X	X	X	X (BSW)	
DNPW	X	X	X					
IMA	X	X	X	X	X			X
LTA							X	

Table 3: Planned Support for V2V Safety Warnings Among Auto Manufacturers[9]

The single 10 megahertz channel dedicated to V2V within DSRC therefore provides all necessary safety information through the BSM, which will manifest in safety warnings through OEM adoption of applications as they see fit.

i) Challenges to DSRC V2V Efficacy

For those safety warnings that are adopted by OEMs, a range of environmental and design considerations impact the efficacy of V2V communications. Efficacy in DSRC manifests as the range (distance) for reliable transmissions, which is in turn influenced by the packet error rate, received signal strength, and other factors. A 2009 research report, for example, noted that the positioning of DSRC radios on vehicles was a significant contributor to system performance.[10] And NHTSA notes that urban canyons can impact DSRC as well as GPS (which DSRC relies on for vehicle positioning and system timing information).

These factors pose challenges for the efficacy of DSRC V2V safety warnings. Extensive field trials during the 2007-2010 period conducted in five nations reveal the extent of these challenges. Using commercial off-the-shelf technology to test realistic implementation parameters, researchers from Choda Wireless and the

[9] Mike Shulman, "V2V Advancements in the Last 12 Months: CAMP and Related Activities", Ford, April 22, 2014. Accessed on October 10, 2014, at: http://umtri.umich.edu/content/2014.GlobalSymposium.Shulman.pdf (CAMP is the Crash Avoidance Metrics Partnership, a V2V research collaboration among auto OEMs.).

[10] "Final Report: Vehicle Infrastructure Integration Proof of Concept Results and Findings", p.25, submitted to the Research and Innovative Technology Administration of the US Department of Transportation, May 19, 2009.

University of South Australia found that the *maximum* effective range for V2V warnings was 50 meters – well below NHTSA's stated goal of 300 meters.[11]

The researchers also accounted for 'human in the loop' factors and found that in general, DSRC warning times were insufficient to enable drivers to comprehend them and take sufficient action, as shown in Figure 2. Advanced receiver technology was required to provide sufficient warning time to drivers.

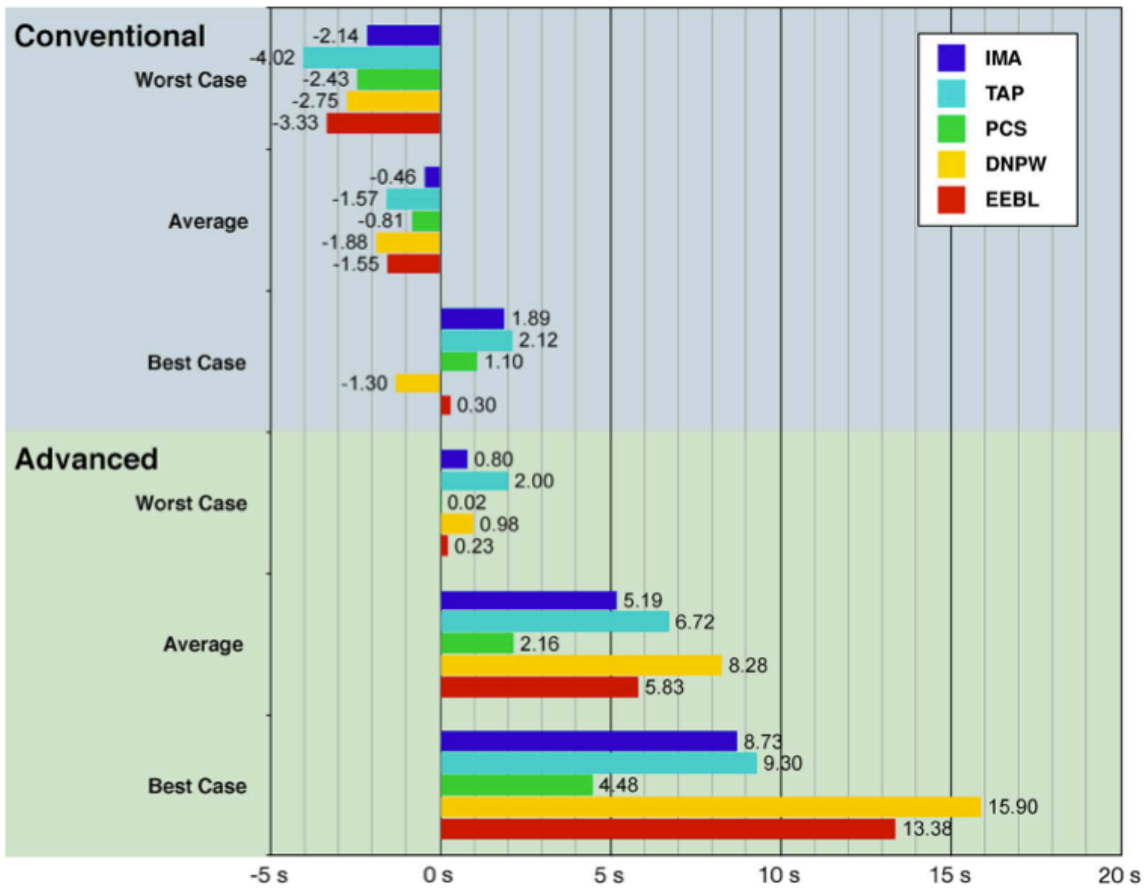

Figure 2: V2V Driver Warning Time Field Research Results[12]

Another recent field study found that the effective range of DSRC is reduced for the most critical use cases involving high relative vehicle velocity. The researchers concluded that:

[11] Paul Alexander, David Haley, and Alex Grant, "Cooperative Intelligent Transportation Systems: 5.9-GHz Field Trials", *Proceedings of the IEEE* (invited paper), 2010. 50 meter effective range results were found when testing a 400 byte BSM transmitted at 6 Mbps. NHTSA notes on p.96 of the *V2V Report* that BSMs are likely to be transmitted at 6 Mbps with an average size of 3,000 bits (approximately 375 bytes).
[12] Ibid. The horizontal axis in this chart represents "excess stopping plus reaction time", where a negative time implies an unavoidable collision.

At high speeds, such as when two vehicles are driving past on opposite sides of a non-segregated trunk road, the large reduction in effective range might reveal to be a problem for safety applications. Indeed, the effective range decreases to a point that IVC [inter-vehicle communications] are not advantageous any more compared to on-vehicle exteroceptive sensors such as LIDARs or RADARs, with ranges in the 100-200 metres interval.[13]

In light of uneven OEM support of V2V safety warning applications, likely variability in radio equipment among OEMs, and effective range inconsistency as a function of use cases, the efficacy of the core functionality of DSRC is uncertain.

c) Other DSRC Services

A variety of other services have been envisioned by DSRC stakeholders, though these services are generally ancillary to NHTSA's core interest in V2V safety and are at an even more nascent stage of development.

Within the DSRC system architecture, access to these services is advertised and managed by a control channel, and the services can be provided on the other DSRC channels, as well as the service interval of the control channel.

NHTSA's research report notes that a two-radio solution is preferable for DSRC implementations.[14] A single radio solution would require time division of DSRC services between a control interval and a service interval, with BSMs transmitted during the control interval. Combined with a small guard interval to space the transmissions, a single radio solution therefore would reduce BSM capacity to 46%, relative to a dedicated BSM radio.[15] NHTSA therefore correctly prioritizes the core V2V safety applications over other DSRC services by recommending a two-radio solution that enables dedicated BSM transmissions.

In a two-radio approach, non-V2V services will continue to operate on a time division basis. The IEEE 1609.4 standard divides DSRC transmissions into 100 millisecond intervals, alternating between the control channel and service channels for 50 milliseconds at a time. All DSRC functions outside of BSM safety warnings will be subject to this time division – checking the control channel for services, then switching to the relevant service channel to utilize the desired service. As NHTSA notes, this time division inherently reduces the capacity

[13] Sébastien Demmel, Alain Lambert, Dominique Gruyer, Andry Rakotonirainy, Eric Monacelli, "Empirical IEEE 802.11p Performance Evaluation on Test Tracks", *2012 IEEE Intelligent Vehicles Symposium*, June 2012.
[14] *V2V Report*, p.94.
[15] *V2V Report*, pp.95-96.

available.[16] The logic of the DSRC protocol therefore regards all services that are not BSM safety warnings as a secondary priority.

This architecture makes sense from the perspective of the primary governmental interest in road safety, and also from the perspective of the performance needs of non-BSM services. Though these other services are not fully specified or extensively tested, they appear less uniformly time-sensitive, and/or less unique to DSRC.[17] A comprehensive review of these ancillary DSRC services is not possible since there is no fully developed specification or implementation plan. For example, a catalogue of potential V2I safety-ancillary applications was presented recently by DSRC stakeholders in IEEE discussions,[18] but close examination reveals many of these applications to be in fact core functions enabled by BSMs (thus, not V2I).[19] We also note that DSRC stakeholders highlight applications that are safety-adjacent, rather than those that are commercial in nature,[20] and many of the safety-adjacent applications are unlikely to require real-time communications in the manner that BSMs require.[21]

V2I applications would, of course, rely on as-yet undeployed roadside infrastructure, and the responsibility, planning, and funding for such infrastructure remains unspecified. NHTSA notes that it does not expect wide deployment of roadside infrastructure in the near term.[22] Many V2I applications are intended to supplement V2V functions, as well as capabilities provided by other existing technologies, such as radar, light detection and ranging (LiDAR), and mobile and Wi-Fi networks. Therefore, the outlook for V2I applications remains highly uncertain, particularly in light of the fact that OEMs are likely to provide uneven support for even the core safety warnings enabled by BSM data.

NHTSA notes several V2I applications that are “contemplated, but not yet developed”, shown in Table 4.[23]

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[16] *V2V Report*, pp.95-96.
[17] Time sensitivity in this context is relative to BSM latency needs, measured in milliseconds. By this standard, applications that can tolerate several seconds of latency are not time sensitive.
[18] John Kenney (Toyota) et. al., “A Response to the Rechannelization Proposal”, *IEEE document 802.11-14/1101r0*, September 5, 2014.
[19] Such as pre-crash mitigation, tracked vehicle safety, and left turn assist.
[20] Commercial applications may include insurance notifications, rental car processing, or car park payment processing, for example. NHTSA notes that commercial applications are the primary use case for European DSRC implementations. *V2V Report*, pp.116-118.
[21] Work zone warnings, R.E.S.C.U.M.E., and automated advanced crash notifications, for example, can tolerate latency of several seconds.
[22] *V2V Report*, p.13.
[23] *V2V Report*, p.32.

Warning	*Purpose*
Red Light Violation Warning	May provide in-vehicle alerts to drivers about potential violations of upcoming red lights, based on vehicle speeds and distances to intersections.
Curve Speed Warning	If a driver's current speed is unsafe for traveling through an upcoming road curve, this technology may alert the motorist to slow down.
Stop Sign Gap Assist	This technology may assist drivers at stop-sign-controlled intersections via vehicle gap detections, alerting motorists when it is unsafe to enter intersections.
Reduced Speed Zone Warning	This technology may assist drivers in work zones, by issuing alerts to drivers to reduce speed, change lanes, and/or prepare to stop.
Spot Weather Information Warning	This technology may provide alerts or warning to drivers about weather events and locations, based upon information from weather data collection services.
Stop Sign Violation Warning	Based on vehicle speeds and distances to intersections, this technology may provide alerts to drivers about potential violations of upcoming stop signs.
Railroad Crossing Violation Warning	May assist drivers at railroad crossings, alerting motorists when it is unsafe to cross the railroad tracks.
Oversize Vehicle Warning	Drivers of oversized vehicles may receive an alert to take an alternate route or a warning to stop, based upon information about bridges/tunnels.

Table 4: Potential V2I Applications[24]

In reviewing the potential V2I applications offered by DSRC stakeholders, it is apparent that existing technologies perform many of the same functions. For example, researchers have devised methods to detect traffic light status through a combination of cameras and maps.[25] Google's latest efforts have proven that a wide range of driving circumstances can be navigated through current autonomy technology.[26]

[24] *V2V Report*, pp.32-33.
[25] Nathaniel Fairfield and Chris Urmson, "Traffic Light Mapping and Detection", accessed October 13, 2014 at: http://static.googleusercontent.com/media/research.google.com/en/us/pubs/archive/37259.pdf
[26] See, e.g., Sebastian Anthony, "Google's self-driving car passes 700,000 accident-free miles, can now avoid cyclists, stop at railroad crossings", *ExtremeTech*, April 29, 2014. Accessed October 13, 2014 at: http://www.extremetech.com/extreme/181508-googles-self-driving-car-passes-700000-accident-free-miles-can-now-avoid-cyclists-stop-for-trains.

If these types of applications are ultimately implemented through DSRC, it is not likely that they will uniformly require the low degree of latency that BSMs require. Though driving scenarios exist where these applications may be time-sensitive, it is unlikely that more than one will arise at a time. Latency tolerance of several seconds implies significant flexibility for coexistence purposes. Since DSRC transmits in 100 millisecond intervals and operates on a fault-tolerant retransmission basis, over several seconds a message can be transmitted dozens of times, greatly enhancing the probability of successful communication.

NHTSA is cautious in its views toward V2I applications, noting that V2V BSM service "should not be compromised due to broadcasting more data for V2I."[27] This is an appropriate area of concern for NHTSA, given the wide variety of V2I applications envisioned by DSRC stakeholders, many of which are commercial in nature. Parking lot payments, music and video uploads, rental car processing, and drive-thru payments are some of the commercial applications that have long been envisioned for DSRC.[28] These applications and others have no relation to safety objectives, and as NHTSA notes, may harm the safety functionality of DSRC. In fact, ABI Research estimates that by 2027, 30% of all DSRC applications will be unrelated to safety, such as media sharing and traffic information.[29]

These observations have implications, discussed below, for the optimal design of DSRC and its ability to successfully coexist with Wi-Fi services.

4) Implications for DSRC System Design and Wi-Fi Coexistence

We have reviewed DSRC system functions and potential implementation paths, observing that V2V BSM safety applications represent the core governmental interest in DSRC, and though questions of uniform adoption and efficacy exist, these services will likely be provided over a single dedicated radio. We have also observed that other (non-BSM) DSRC applications will likely be provided by a second radio that divides its time between a control channel (broadcasting availability of services) and the services themselves. These ancillary services are not fully specified and their ultimate path to broad adoption remains unclear; however, if broadly adopted, the time sensitivity of these services (as measured in milliseconds) is uneven, with many services able to tolerate a delay of seconds or more, implying significant fault tolerance and robust coexistence potential.

Translating these system requirements to bandwidth requirements, we conclude that the core functionality of DSRC, being V2V BSM safety warnings, requires a

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[27] *V2V Report*, p.33.

[28] See, e.g., Jinhua Gao, "Vehicle Safety Communications in DSRC", 2006 US Army VI Winter Workshop. Accessed on October 13, 2014 at: http://groups.engin.umd.umich.edu/vi/w5_workshops/guo_DSRC.pdf.

[29] ABI Research, "By 2027, 30% of V2X Applications will be Non-safety Related, Driven by Third-party Developer Ecosystem", August 23, 2013. Accessed October 13, 2014 at: https://www.abiresearch.com/press/by-2027-30-of-v2x-applications-will-be-non-safety-.

single 10 megahertz channel. Other DSRC safety services, if deployed, may at times require low latency; therefore, it may be beneficial to dedicate another 10 MHz channel for this purpose. Doing so also requires a control interval to manage access to services, which could be done on the same channel (dividing time equally between control and services per the IEEE 1609.4 standard), or potentially through a separate dedicated service channel.[30] Therefore, time-sensitive V2I services may benefit from a supplemental 10 megahertz channel, or at most, two 10 megahertz channels.[31] In total, therefore, combined with a dedicated BSM channel, time-sensitive safety services of DSRC should require no more than two or, at most, three 10 megahertz channels.

As NHTSA notes, discussion of coexistence between Wi-Fi and DSRC taking place within the IEEE has not yielded a consensus result.[32] For that reason, simplification of spectrum sharing through frequency separation is worthy of consideration. Doing so would enable more robust use of the 5.9 GHz band, and afford greater protection for V2V services at the core of the government's interest.

An examination of Wi-Fi and DSRC channelization reveals the opportunity to both afford the highest level of protection for critical DSRC services while more fully enabling utilization of spectrum resources by extending Wi-Fi access. As shown in Figure 3, three DSRC channels are allocated above the highest Wi-Fi channel as defined by the 802.11ac standard. This means that up to 30 megahertz can be made available exclusively for DSRC while enabling the latest Wi-Fi technology. We note that this would require Wi-Fi to refrain from use of a 20 megahertz channel that is within the IEEE band plan.

[30] Note however that a dedicated service channel would still be subject to time division under IEEE 1609.4, since the second DSRC radio needs to switch back to the control channel to listen for the availability of services. DSRC system architecture therefore regards V2I services as less latency-sensitive than V2V BSMs.

[31] Communications security can also be provided on the service channel interval of the control channel, or on a separate service channel. The latency requirements associated with security services are a function of architecture decisions, which do not appear to have been made at this time. Therefore, security is another area of DSRC that can be optimized in the current pre-deployment phase in order to advance road safety and spectrum utility objectives.

[32] *V2V Report*, pp.89-91.

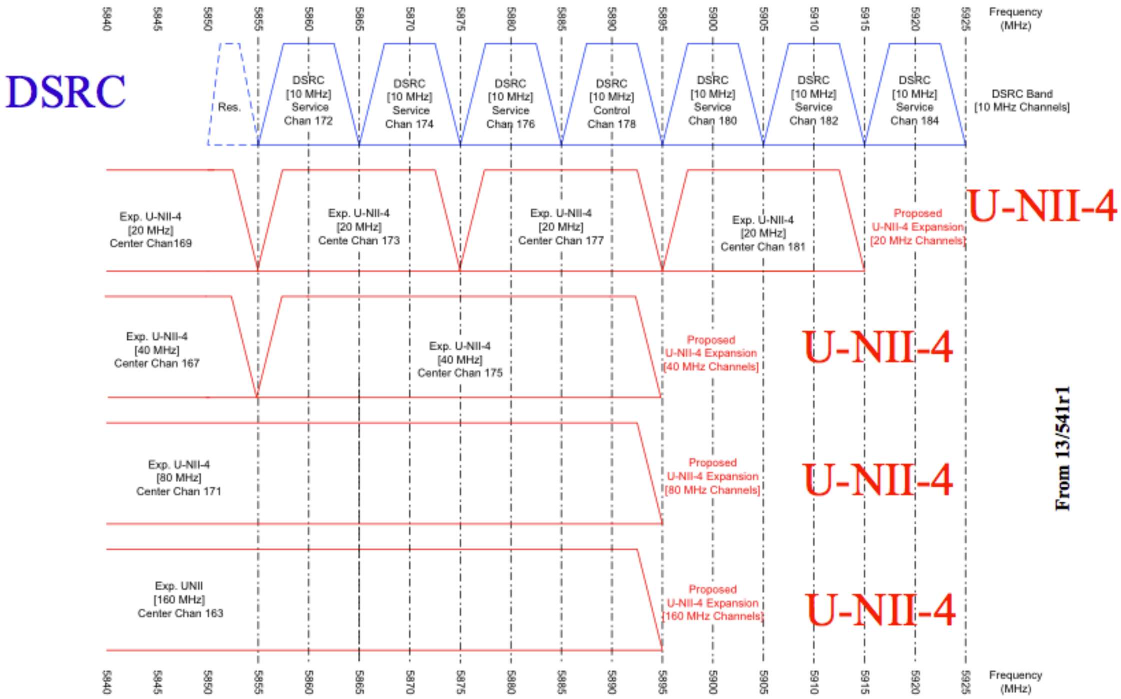

Figure 3: DSRC and Wi-Fi (UNII-4) Channelization[33]

Others share the view that Wi-Fi and DSRC channelization affords an opportunity for coexistence through frequency separation. In May 2013 comments to the FCC, Qualcomm noted that, "placing the uppermost 20 to 30 MHz spectrum off limits for Wi-Fi and providing exclusive use for DSRC safety services within that portion of the spectrum will provide absolute protection for the DSRC safety services without sacrificing any spectrum useful for 802.11ac-based Wi-Fi."[34]

Providing DSRC with up to 30 megahertz of exclusive-use spectrum would afford critical, time-sensitive DSRC transmissions with the highest probability of success. As the literature and field research to date has shown, the reliability and efficacy of DSRC in enhancing road safety is not certain, so the core governmental interest in DSRC would be enhanced through frequency separation. This approach also supports a key governmental mission – maximizing the utility of the wireless spectrum.

In implementing frequency-separation coexistence, the DSRC channel plan will require adjustment, moving the V2V BSM function from channel 172 to the 180-184 range. Similarly, the control channel, currently envisioned for channel 178, would move upward. Four DSRC channels would remain co-channel with the new Wi-Fi band, to be used as spillover capacity for non-critical DSRC services.

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[33] Jim Lansford, "CCA Issues for DSRC Coexistence", *IEEE document 802.11-14/0532r0*, presentation to IEEE 802.11 Regulatory Subcommittee for DSRC Coexistence Tiger Team, April 20, 2014.

[34] Comments of Qualcomm Inc. before the Federal Communication Commission, ET Docket 13-49 (filed May 28, 2013), p.iv.

Importantly, given the pre-deployment state of DSRC, a channel plan shift will not require changes to existing products or services. Several technical considerations associated with this change are nonetheless worth identifying.

5) Technical Considerations in DSRC Rechannelization

Rechannelization of DSRC to enable exclusive-use spectrum for critical applications warrants several technical considerations relating to DSRC service provision. These include the impacts of adjacent-band noise, in this case from Wi-Fi and from Fixed Satellite Services, as well as adjacent-channel noise within DSRC itself. We consider each below and its potential impact to critical DSRC services. In general, we find that these factors do not imply reduced performance for critical DSRC services, and in fact offer an opportunity to improve the environment in which critical DSRC services operate.

a) DSRC Adjacent-Channel Noise

In rechannelizing DSRC, consideration should be given to the impact that any changes will have within the DSRC system. Cross-channel interference has long been a known problem in the operation of DSRC, within the currently envisioned channel plan.

Measurement studies in 2007 showed significant packet loss to BSMs when nearby vehicles were transmitting on adjacent service channels.[35] This interference arises when an interfering radio is less than about 20% the distance between a transmitter-receiver pair. In other words, if the intended range of a BSM message is 100 meters, then operating a service channel on a car closer than 20 meters would cause significant packet loss in the BSM.

Cross-channel interference within DSRC is influenced by frequency adjacency, relative transmit power, and data load. NHTSA notes that core BSM safety applications should retain priority over V2I and other less-critical services in DSRC implementations, and that this will be an ongoing area of research.[36] Rechannelization of DSRC is therefore consistent with this ongoing area of system development, and affords the opportunity to improve cross-channel interference issues that exist under current DSRC thinking. For example, DSRC service channel utilization could be designed in a manner that prioritizes according to frequency, with service channels that are 'farthest away' from the V2V channel being activated first.

b) Adjacent-Band Noise from Wi-Fi and Fixed Satellite Services

[35] Vinuth Rai, *et al*., "Cross Channel Interference Test Results: A Report from the VSC-A Project" (July 2007) *available at* https://mentor.ieee.org/802.11/dcn/07/11-07-2133-00-000p-cross-%20%20channel-interference-test-results-a-report-%20from-the-vsc-a-project.ppt.

[36] *V2V Report*, pp.11-14, 33.

The impact of noise from adjacent-band services on DSRC safety services should also be considered. Current allocations place Wi-Fi at the lower band edge of DSRC, and Fixed Satellite Services (FSS) at the upper band edge. In any rechannelization of DSRC, this situation would remain unchanged; however, there is an opportunity in extending Wi-Fi into the 5.9 GHz band to specify out-of-band emissions from Wi-Fi in a favorable manner for DSRC.

Current FCC rules for Wi-Fi in 5725-5850 MHz frequency range (also known as "UNII-3") limit out-of-band emissions to -17 dBm/MHz within 10 megahertz of the band edge (5850 MHz), and to -27 dBm/MHz beyond 10 megahertz of the band edge. In practice, the IEEE spectral mask for Wi-Fi is approximately -40 dBr at 20 megahertz from the band edge. At 30 dBm Wi-Fi transmit power, as permitted under current FCC rules, -40 dBr leads to -10 dBm at 20 megahertz from the band edge, or -23 dBm/MHz out-of-band emission potential into DSRC. Rechannelization of DSRC and extension of Wi-Fi into UNII-4 provides an opportunity to ensure that out-of-band emission limits are suitable to preserve critical DSRC safety services operating in the exclusive-use band that is adjacent. This dynamic is outlined in the below band plans, Figures 4 and 5.

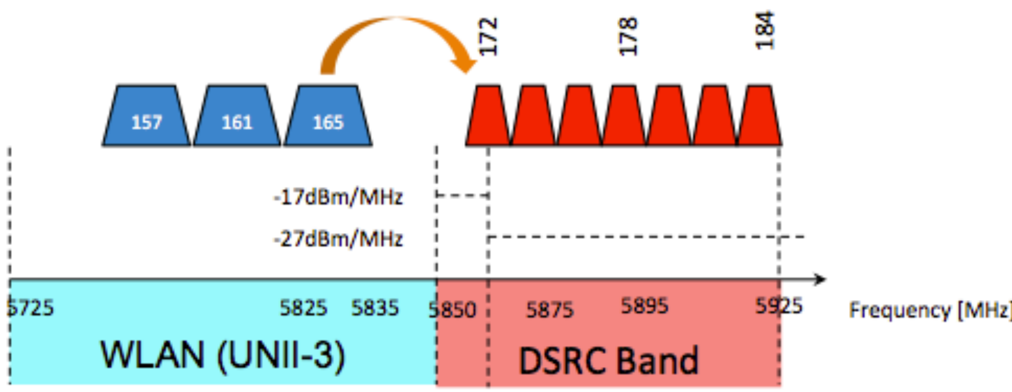

Figure 4: Out-Of-Band Emissions from Wi-Fi Under Current FCC Rules[37]

[37] Tevfik Yucek, Xinzhou Wu, "Technical Discussion on Rechannelization for DSRC band Coexistence", *IEEE document 802.11-14/0819r0*, presented July 11, 2014.

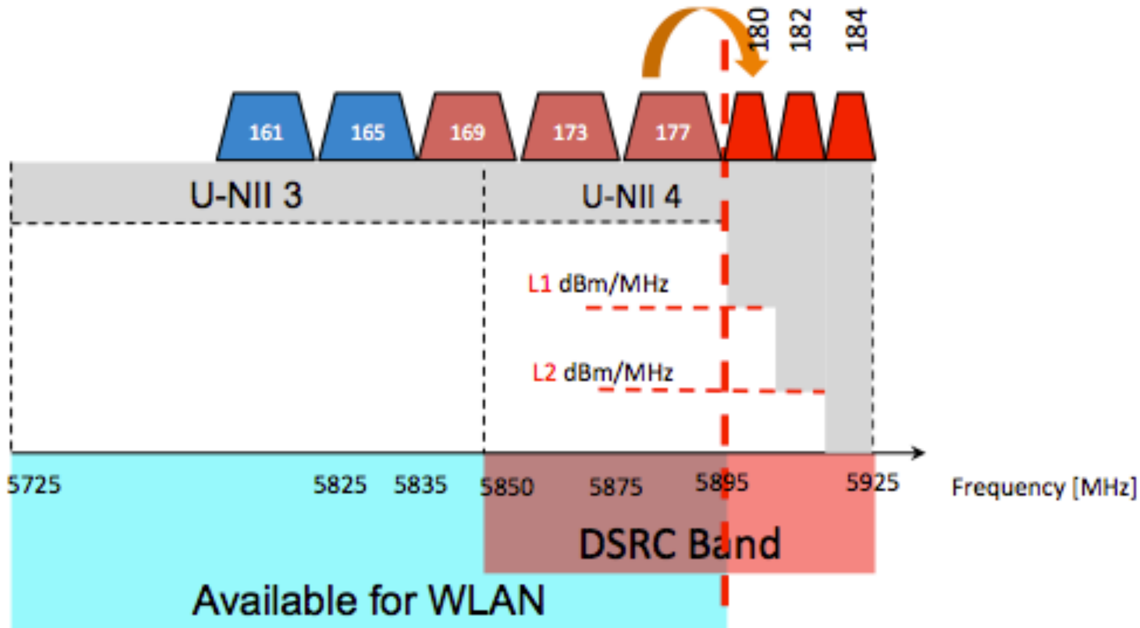

Figure 5: Out-of-Band Emissions To Be Specified Through DSRC Rechannelization & Wi-Fi Extension[38]

FSS services will remain at the adjacent upper band edge of DSRC; this allocation has existed for many years, and DSRC stakeholders will have anticipated the RF environment associated with FSS uplinks that use the 5.9-6.4 GHz band. In IEEE coexistence discussions, little information has been made available from the DSRC community to assess how any shift in DSRC channelization would impact services as a function of adjacent band FSS. The risk of adjacent-band FSS noise would arise in locations that are geographically proximate to FSS uplink Earth stations. However, NHTSA notes that these stations are typically in rural and remote locations, and that there has been an agreement between DSRC and FSS to coordinate.[39] Though additional information would be useful to verify adjacent-band coexistence between FSS and DSRC under a rechannelized approach, we are aware of no evidence to suggest that it would materially impact DSRC safety functions.

6) Conclusion

In reviewing the literature and technical requirements associated with nascent DSRC technology, we find that the safety services at the core of NHTSA's interest are served through V2V BSMs that utilize a dedicated radio and channel to enable safety warnings. The broad adoption and efficacy of BSM-based V2V safety warnings is uncertain in light of uneven support among OEMs, variable field test results, and the availability of other technologies. Ancillary V2I DSRC services are less specified and even more uncertain, and their broad use for

[38] Ibid.
[39] *V2V Report*, p.89.

commercial purposes may in fact diminish the performance of V2V safety services.

For that reason, we recommend that critical safety DSRC services – consisting mainly of V2V BSM safety warnings, but also potentially a subset of as-yet-undeveloped V2I services – use up to three dedicated 10 megahertz channels. This approach optimizes the safety purposes of DSRC, and enables expanded use of the 5.9 GHz frequency band through new Wi-Fi services.

Rechannelizing DSRC in this fashion offers the potential to improve its operating parameters and resultant safety outcomes, and also paves the way for significant consumer benefits associated with the latest IEEE wireless networking technology, 802.11ac. At this early stage of DSRC technology development, there is reason for optimism around coexistence in the 5.9 GHz band. Our review has outlined how this outcome can be advanced through frequency separation measures, thus serving as an important contribution to the technical record as the government looks to advance the twin goals of road safety and economic growth.